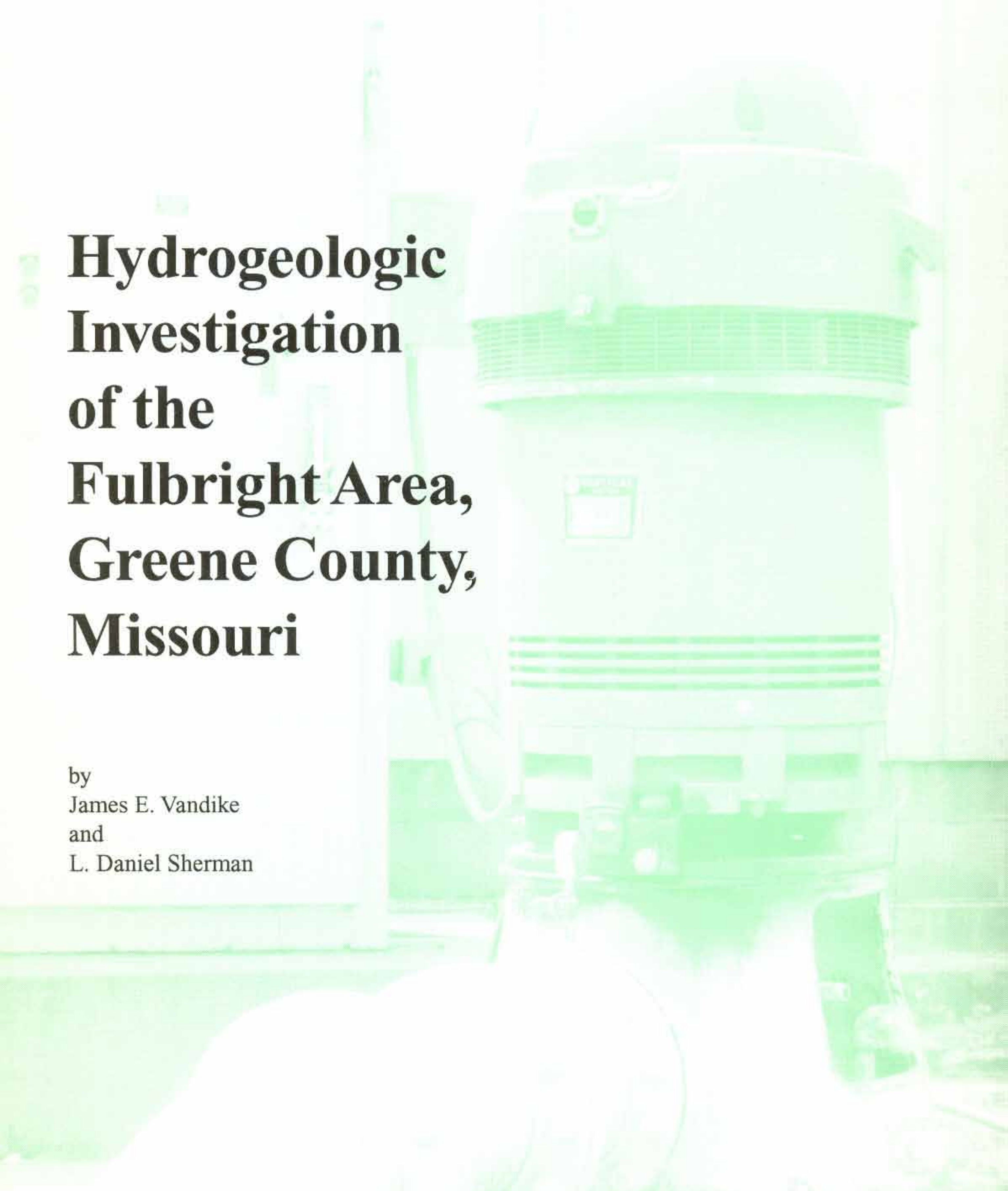

Hydrogeologic Investigation of the Fulbright Area, Greene County, Missouri

by
James E. Vandike
and
L. Daniel Sherman

Missouri Department of Natural Resources
Division of Geology and Land Survey
Water Resources Report Number 43

Cover Photo: *Fulbright Well No. 1. The 300 horsepower vertical line shaft turbine pump can provide more than 2000 gallons of water per minute. Photo by James E. Vandike.*

HYDROGEOLOGIC INVESTIGATION OF THE FULBRIGHT AREA, GREENE COUNTY, MISSOURI

by

James E. Vandike, Geologist
Water Resources Program

and

Daniel Sherman, Geologic Technician
Geological Survey Program

1994

This project was funded by Region 7, Environmental Protection Agency, under a Management Assistance Cooperative Agreement with the Missouri Department of Natural Resources

MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey
P.O. Box 250,
Rolla, Missouri 65401
(314) 368-2100

Library of Congress Catalog Card Number: 94-77004
Missouri Classification Number: GE 9:43

Vandike, James E., and Sherman, Daniel, 1994, ***Hydrogeologic Investigation of the Fulbright Area, Greene County, Missouri,*** Missouri Department of Natural Resources, Division of Geology and Land Survey, Water Resources Report Number 43, 112 p., 36 figs., 1 tbl., 1 appendix.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

EXECUTIVE SUMMARY

A one-year hydrogeologic investigation was conducted in the northwestern part of Springfield and the adjacent part of Greene County to determine the hydrologic characteristics of the groundwater system in the area. There are three sites in this area where groundwater contamination is known to have occurred, or where the disposal of wastes has created a threat of groundwater contamination. These sites are the Fulbright and Sac River landfills, and the North U Drive area. A major concern in this study was the effects that Fulbright well #1 has on the direction and rate of groundwater movement in the study area.

Water levels from a network of 16 observation wells (12 open to the Ozark aquifer and four completed in the shallower Springfield Plateau aquifer), were monitored from late March 1993, through January 1994. Four of the wells were equipped with digital water-level recorders to measure hourly water levels. Water levels in the other wells were either measured manually with an electric probe, or using existing air lines and pressure gauges.

Water-level data collected from wells open to the Ozark aquifer show that when Fulbright well #1 is not operating, the potentiometric surface of the Ozark aquifer between Fulbright Water Treatment Plant and the Northwest Wastewater Treatment Plant has a very low gradient toward Fulbright well #1. However, after Fulbright well #1 has been pumping for an extended period, it creates a cone of depression that extends more than a mile from the well. If Fulbright well #1 is operated at least one month per year, its capture zone likely includes the Ozark aquifer beneath the Fulbright Landfill and the North U Drive area.

Water-level data collected at Fulbright well #2 shows that there is a downward-flow potential between the Springfield Plateau aquifer and the Ozark aquifer at the southeastern end of the Fulbright Landfill at all times. The head difference between the two aquifers increases from about 45 ft when Fulbright well #1 is not pumping to about 130 ft when the well has been operating for two months.

Hydrologic analyses show that under certain conditions it is possible for groundwater in the Fulbright Landfill to have moved to Fulbright well #1, either through the Springfield Plateau aquifer or through the Ozark aquifer. However, water-quality data from well #1 does not indicate that this has occurred. A monitoring well open to zones above the Northview Formation should be placed between the Fulbright Landfill and Fulbright well #1 to see if contaminants are migrating toward the well in the Springfield Plateau aquifer. Fulbright well #2 can be used to determine if contaminants from the Fulbright Landfill have moved downward through the Northview Formation into the Ozark aquifer, and are moving toward well #1 through the Ozark aquifer.

Data collected during this study, combined with existing information, indicates that Fulbright Landfill was not a source of contaminants for the North U Drive site. Previous dye tracing studies and water-level data show groundwater in the Springfield Plateau aquifer at North U Drive flows north toward the Fulbright Landfill. Based on water-level data collected during this study, groundwater in the Ozark aquifer in the North U Drive area moves toward Fulbright well #1 at all times.

INTRODUCTION

Groundwater in the northwestern part of Springfield, Missouri, and the adjacent unincorporated area of Greene County, has been extensively studied during the past several years. This area, referred to as the Fulbright area (fig. 1), contains several sites where past waste disposal practices and accidental spills may have locally impacted groundwater quality. Two landfills, both now closed, operated in this area on the floodplains of the Little Sac River and its tributary, the South Dry Sac River. The Fulbright Landfill operated from about 1962 to 1969, and disposed of wastes in trenches constructed in alluvium on the floodplain of South Dry Sac River between its confluence with Pea Ridge Creek and near old Highway 13. The Sac River Landfill operated from 1968 to 1974, and is downstream of new Missouri Highway 13 on the north side of the Little Sac River. Reportedly both landfills received a variety of waste products including liquid and solid industrial wastes containing high levels of metals, strong acids, and cyanide wastes (SCS [Stearns, Conrad and Schmidt Consulting Engineers, Inc.], 1988).

In 1983, residents in the North U Drive area began complaining of taste and odor problems in private domestic wells in the subdivision. Subsequent sampling showed most of the contaminants to be petroleum-related hydrocarbon compounds, although a few chlorinated volatile organic compounds were identified (Ecology and Environment, 1992). Water lines were installed to provide water from Springfield City Utilities to most of the residences in the North U Drive area, and most of the private wells (68) were plugged to help prevent further contamination of deeper aquifer zones.

In January 1993, the Missouri Department of Natural Resources, Division of Geology and Land Survey (DGLS), entered into a Management Assistance Cooperative Agreement (MACA) with Region 7 of the Environmental Protection Agency to conduct a limited groundwater study in the Fulbright area. Existing data show that recent samples of leachate, collected at both Sac River and Fulbright landfills, contained high lead concentrations; elevated lead levels were also found in monitoring wells at both landfills (SCS , 1988). Water sampling in the North U Drive area also showed elevated lead levels in several wells (Ecology and Environment, 1992). The major objective of the present study is to determine if the Fulbright or Sac River landfills may have impacted groundwater quality at the North U Drive site. Also, previous work by SCS (1988) indicated that deep groundwater movement was to the northwest away from the City of Springfield. However, the SCS study (1988) did not consider the effects of pumping Fulbright well #1, which is less than 2,000 ft from the southeast end of Fulbright Landfill.

The department's Division of Geology and Land Survey undertook several activities to address the aforementioned concerns. Existing water-quality data from all three sites, plus data supplied by Springfield City Utilities from Fulbright well #1, were examined. A well inventory was conducted to identify groundwater users in the Fulbright area. Well owners were contacted and asked to provide information about their wells including total depth and casing depth. A network of water-level monitoring wells was established, and water levels were measured at regular intervals. A total of 16 wells, 12 open to the Ozark aquifer and four completed into the Springfield Plateau aquifer, were monitored from late March, 1993, through the completion of the study. Four of the wells were equipped with Stevens model 7001 digital water-level recorders to measure hourly water-level changes. The remaining wells were measured by hand using either a Solinst electric water-level probe, or by using previously installed air lines and pressure gauges. A aquifer test lasting more than 60 days was conducted in August, September, and early October 1993 when Springfield City Utilities was pumping Fulbright well #1. The monitoring well network served as observation wells during the pumping test. Water-level data were used to construct two potentiometric maps; one from data collected before Fulbright well #1 was activated, and the other after two months of nearly continuous pumping.

Selected wells were geophysically logged with a gamma probe to determine the thickness of the Northview Formation at those wells. Existing well logs on file with the Division of Geology and Land Survey were also used to determine the thickness of the Northview Formation in the Fulbright area. Well logs and recent geologic mapping by Middendorf (1990) were used to construct a southwest to northeast geologic cross-section through the Fulbright area.

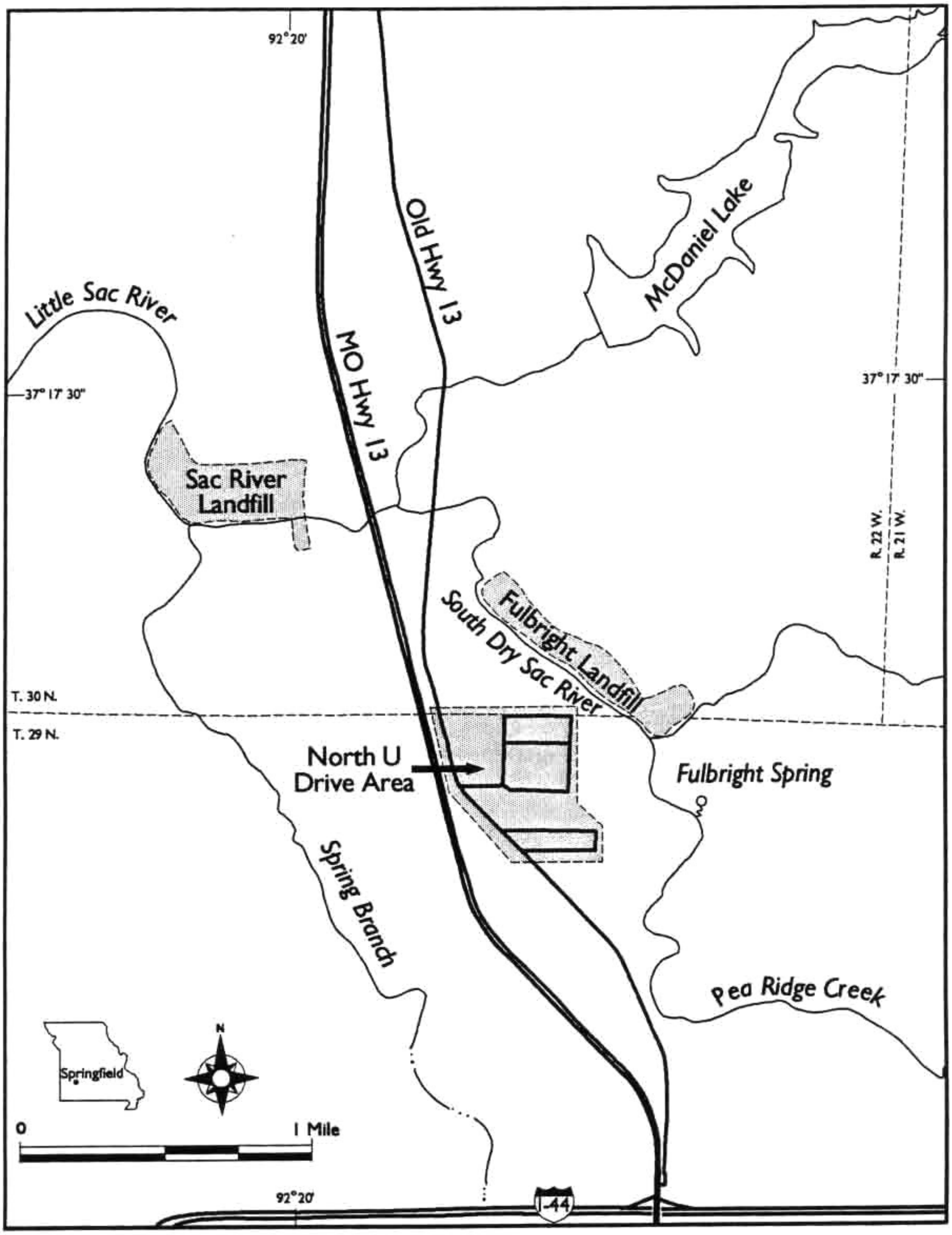

Figure 1. *Location map showing the Fulbright area, Greene County, Missouri.*

ACKNOWLEDGMENTS

Numerous people and several agencies provided assistance during this study. We appreciate their efforts and thank each of them for the time and resources they expended in helping to make this study a success.

Central Bible College and Southwest By-Products allowed access to their wells for water-level measurements. The National Weather Service at Springfield Regional Airport provided daily climatologic data at the end of each month. The Springfield Department of Public Works provided help in several ways, particularly by allowing access to wells under their control, and by assisting in locating elevation benchmarks for survey work.

Special thanks are extended to Springfield City Utilities. The staff at Fulbright Water Treatment Plant, particularly John Parker and Sherry Raney, assisted this project in numerous ways. They searched their files for historic water-use data, water-quality data, and allowed access to wells and other facilities under their control. Thanks also go to Dr. John Witherspoon for providing historic water-quality data for Fulbright well #1.

Appreciation is also extended to other staff at the Division of Geology and Land Survey that assisted in this project. Ben Pendleton, geologic technician, assisted Dan Sherman in conducting the private well survey. Phillip Streamer, graphic artist, produced the maps contained in the report. Susan C. Dunn, graphic artist, assisted in the typesetting and layout of the final report. Their efforts are very much appreciated.

GEOLOGIC SETTING

Stratigraphy

The Fulbright area is underlain by Mississippian age and older sedimentary rocks that have a total thickness of more than 2,000 ft. The surficial bedrock units in the area are Mississippian age cherty limestones and shale. Lower Ordovician and Cambrian sedimentary rocks underlie the Mississippian rocks at depth. Precambrian igneous and metamorphic rocks underlie the Paleozoic sedimentary rocks.

The Burlington-Keokuk Limestone is the youngest bedrock unit exposed in the Fulbright area, and is the surface bedrock unit over much of area. It consists of up to about 130 ft of fossiliferous limestone and cherty limestone. It is underlain by lower Osagean Series carbonates and cherty carbonates including the Pierson, Reeds Spring, and Elsey formations, which reach a combined thickness of nearly 120 ft in the area. Combined, the above units range from less than 100 ft to about 225 ft thick.

The Kinderhookian Series is represented in the area by the Northview Formation and the Compton Formation. The Northview Formation consists of 25 to 50 ft of shale and siltstone. In the Fulbright area, it reaches a maximum thickness of about 50 ft near McDaniel Lake, and thins to 25 to 30 ft in the southern part of the study area. Thickness of the Northview Formation in the Fulbright Landfill area is approximately 35 ft. The Compton Formation is a clean limestone containing little chert. The unit is relatively thin in the Fulbright area, ranging from about 10 ft in the northern part of the study area to about 20 ft in the southern part.

The Mississippian strata are underlain by about 1800 feet of Ordovician and Cambrian sedimentary rock. In descending order, the Ordovician strata consist of the Cotter Dolomite, the Jefferson City Dolomite, the Roubidoux Formation, and the Gasconade Dolomite. The Cotter Dolomite consists of about 100-150 ft of dolomite and chert with minor sandstone and shale beds. Chert and shale content is generally less than ten to 15 percent. The most notable sandstone bed, the Swan Creek Sandstone, is about 50 ft below the top of the unit and is from about 5-10 ft thick. The underlying Jefferson City Dolomite is quite similar to the Cotter, but the Fulbright area generally has a higher chert content of about 25 percent. Like the

Cotter, it contains minor shale and sandstone beds. The Jefferson City Dolomite is about 200 ft thick in the Fulbright area.

The Roubidoux Formation, consisting of about 175 ft of interbedded sandstone, sandy dolomite, and cherty dolomite, underlies the Jefferson City Dolomite. Chert content in parts of the Roubidoux can be 50 to 70 percent. The sandstone is generally most prevalent in the lower part of the formation. The Gasconade Dolomite, which is the basal Ordovician unit in this area, is about 350 ft thick. The Upper Gasconade consists of 40-50 ft of clean dolomite with relatively low chert content. The Lower Gasconade, which is about 250 ft thick, is more coarsely crystalline than the Upper Gasconade, and has a much higher chert content. Chert content of the Lower Gasconade varies from less than 10 percent to more than 70 percent. The basal member of Gasconade is the Gunter Sandstone member, which is about 40 feet thick in the Fulbright area. The Gunter is a dolomitic sandstone and sandstone.

Upper Cambrian strata underlie the Ordovician rocks and consist chiefly of cherty dolomites. The Eminence Dolomite is the youngest Cambrian unit in the area, and it consists of about 300 ft of clean dolomite with a low chert content. It is underlain by the Potosi Dolomite. In the Fulbright area the Potosi is relatively thin, consisting of less than 50 ft of relatively chert-free dolomite. In many areas of the Ozarks, the Potosi contains abundant quartz druse. In the Fulbright area, however, the quartz is absent.

The Derby and Doerun dolomite underlie the Potosi Dolomite. Together with the Davis Formation, a shale and siltstone, these units form a confining unit that greatly limits vertical circulation of groundwater. Since wells in the Fulbright area produce only from zones above the Doerun Dolomite, these deeper units will not be discussed.

Structural Geology

Several faults and folds occur in the Fulbright area that affect the attitude of the bedrock, and may affect the movement of groundwater. Middendorf (1992) mapped the geology of the Ebenezer 7.5 minute quadrangle, which covers the Fulbright area. In the area south of the North U Drive site he found evidence of two east-west fault zones with shorter north-south faults between them. The northernmost fault, referred to here as the Fulbright fault, is downthrown on the north side, and may have as much as 80 feet of vertical displacement on the western side of the study area. To the east, displacement decreases markedly. The downthrown side of the southernmost fault is on the south side of the fault. Well log data does not clearly define the presence of this fault, and vertical displacement may be relatively minor.

A structure contour map drawn on the base of the Northview Formation was constructed from well log data (fig. 2). Subsurface data shows that bedrock in the

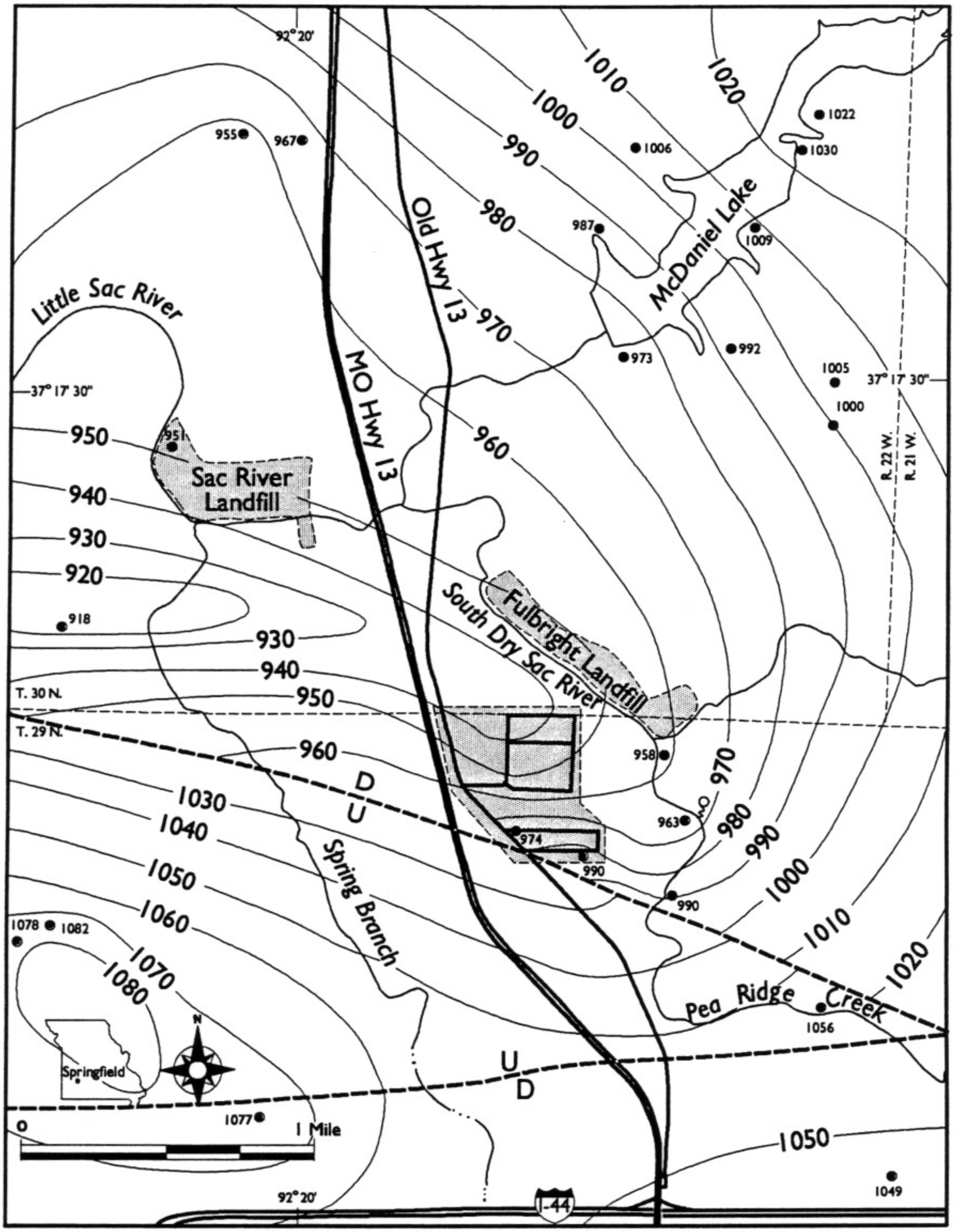

Figure 2. *Structure contour map drawn on the base of the Northview Formation, contour interval = 1 ft. Fault locations from Middendorf, 1992.*

northern part of the study area generally dips to the southwest into a minor syncline that parallels the Fulbright fault and plunges to the west. Well log data and geophysical logs of wells in the North U Drive area indicate that the Fulbright fault may be farther south than the geologic map indicates. South of the fault, bedrock dips generally to the north. Total structural relief in the study area is about 150 ft. Based on the structural contour map, dip of the bedrock in the Fulbright area is less than 100 ft/mi. Figure 3 is a geologic cross-section of the Fulbright area drawn from geologic map and well log data.

Surficial Materials

Bedrock in the Fulbright area is typically overlain by up to 25 feet of unconsolidated residual materials consisting of red clay and silt, and rock fragments. These materials are the insoluble residues that were left after the carbonate rock was chemically weathered. The surficial materials are generally thickest in the gently rolling upland areas, and are thin or absent on hill slopes and valley walls. Average residuum thickness in the area is about 10 ft.

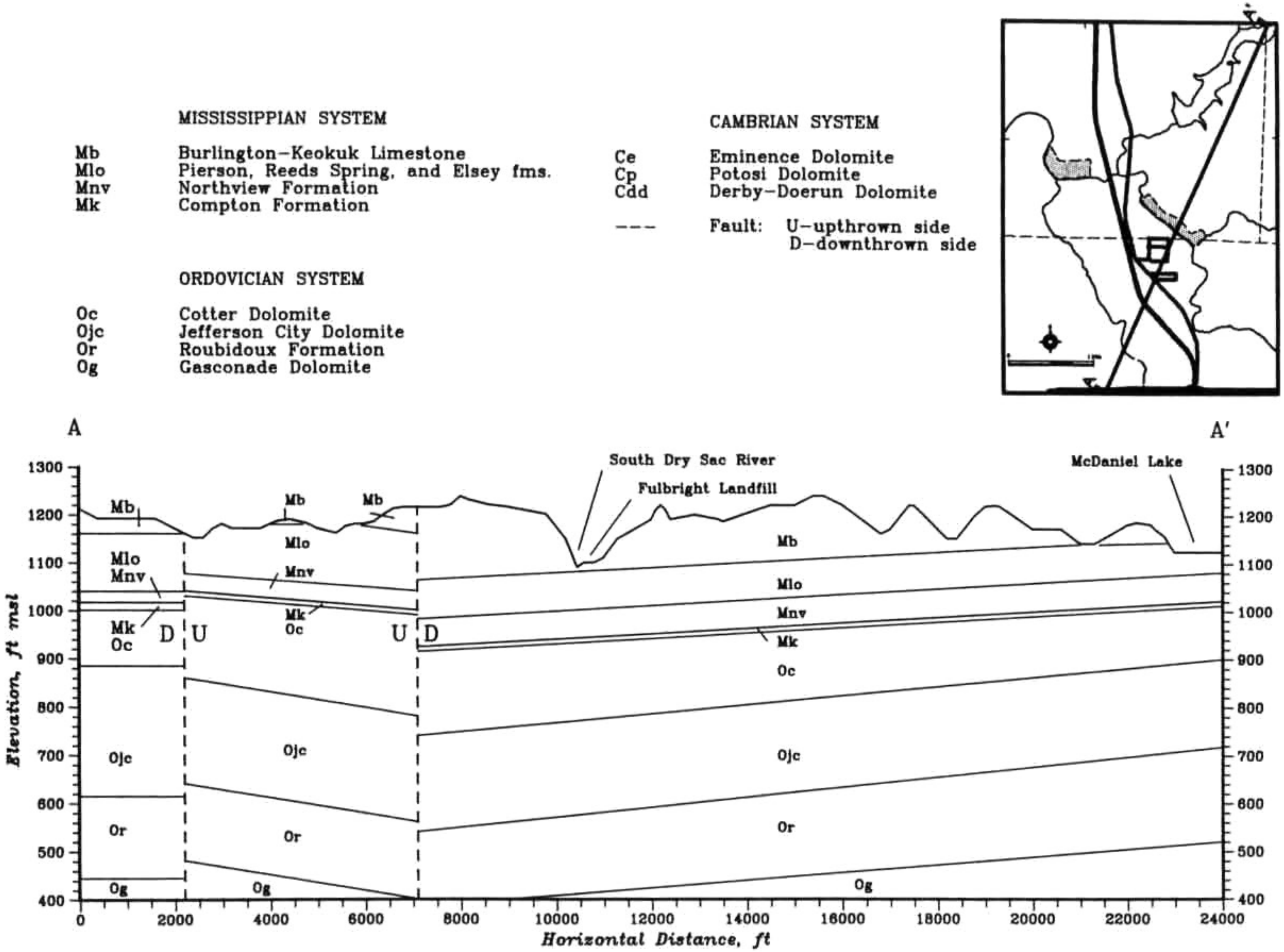

Figure 3. *Geologic cross section of the Fulbright area.*

GENERAL HYDROGEOLOGIC SETTING

The sequence of sedimentary rock underlying the Fulbright area comprises several aquifers and aquitards having specific hydrologic properties that greatly affect the potential migration of contaminants. Two distinct aquifers are present and in use in the Fulbright area; the shallow Springfield Plateau aquifer and the deeper Ozark aquifer. An aquitard called the "Ozark confining unit" separates the two aquifers and impedes the vertical movement of water between them.

Springfield Plateau Aquifer

The Springfield Plateau aquifer is the shallowest bedrock aquifer in the Fulbright area, and is composed of the Mississippian strata above the Northview Formation. It is an unconfined, or water-table, aquifer; the top of the aquifer is the land surface. The aquifer is partially saturated, with saturated thickness being equal to the distance between the water table and the top of the Northview Formation. Depth to water in the aquifer varies with location, but is generally less than 80 ft below land surface in the uplands, and only a few feet below land surface in the valley bottoms.

The Springfield Plateau aquifer in the Fulbright area typically yields 5 to 10 gallons of water per minute (gpm), and is locally used only for private domestic water supply and stock watering. Current private water well construction standards require that, in the Springfield area, new wells be cased through the Northview Formation, and produce from the Ozark aquifer. Thus, only older wells that existed before about 1987 produce from the Springfield Plateau aquifer.

Although the aquifer typically yields only modest amounts of water, much higher yields are possible where a well intersects solution-enlarged openings. The Springfield area is well known for extensive karst development. Springs, caves, and sinkholes abound in the region as well as the Fulbright area. Most of the karst development is in the Burlington-Keokuk Limestone.

Hydraulic conductivity of the Springfield Plateau aquifer varies greatly depending on the location and the presence or absence of solution-enlarged openings.

Hydraulic conductivity is best measured by performing carefully controlled pumping tests on fully penetrating wells. Such tests are routinely performed on high-yield wells drilled for irrigation, industry, or public water supply. They are seldom performed on low-yield private domestic wells. Imes and Emmett (in press) estimate hydraulic conductivity of the Springfield Plateau aquifer to average about 2.5 x 10^{-4} ft/sec (21.6 ft/day or 162 gpd/ft^2). This value was estimated using a previously calibrated steady-state groundwater flow model. The relatively high hydraulic conductivity used in the model likely reflects a value which averages relatively low hydraulic conductivity zones, with the much higher hydraulic conductivities associated with karst conduits. Hydraulic conductivity of the aquifer away from karst conduits or solution-enlarged openings is likely much lower.

Ozark Confining Unit

The Ozark confining unit occurs between the Springfield Plateau aquifer and the underlying Ozark aquifer. In the Fulbright area, it consists of the Northview Formation and the underlying Compton Formation. However, the Northview Formation has the lowest hydraulic conductivity and the greatest thickness of low-permeability shale and siltstone. Although it greatly reduces the vertical movement of water between the overlying and underlying aquifers, the Ozark confining unit is not an impermeable unit. Vertical hydraulic conductivity has been estimated by numerous workers using a variety of methods, but has not been directly measured in most areas. In the Springfield area, Emmett and others (1978) estimated the vertical hydraulic conductivity of the Northview Formation to be about 1 x 10^{-9} ft/sec. Immes (1989) described estimation of the hydraulic conductivity of the Springfield confining unit using a regional groundwater flow model of the Ozark Plateau. A hydraulic conductivity of from 1 x 10^{-8} ft/sec (8.6 x 10^{-4} ft/day or 6.5 x 10^{-3} gpd/ft^2) to 5 x 10^{-8} ft/sec (4.3 x 10^{-3} ft/day or 3.2 x 10^{-2} gpd/ft^2) was calculated, which is several orders of magnitude lower than that of the aquifers above and below it.

Figure 4 shows thickness of the Northview Formation in the study area. The unit is thickest in the northeast part of the area around McDaniel Lake, and it thins to the south and west to a minimum of about 25 ft. In the central part of the study area, including the Sac River Landfill, Fulbright Landfill, and North U Drive areas, it is from about 35 to 45 ft thick.

Ozark Aquifer

The Ozark aquifer is the most widespread and highest yielding bedrock aquifer in southern Missouri. It provides private and public water supply to most of the people in the Ozarks. Additionally, it supplies spring recharge and stream inflow to most of the springs and streams in the Salem plateau. In the Springfield area, the

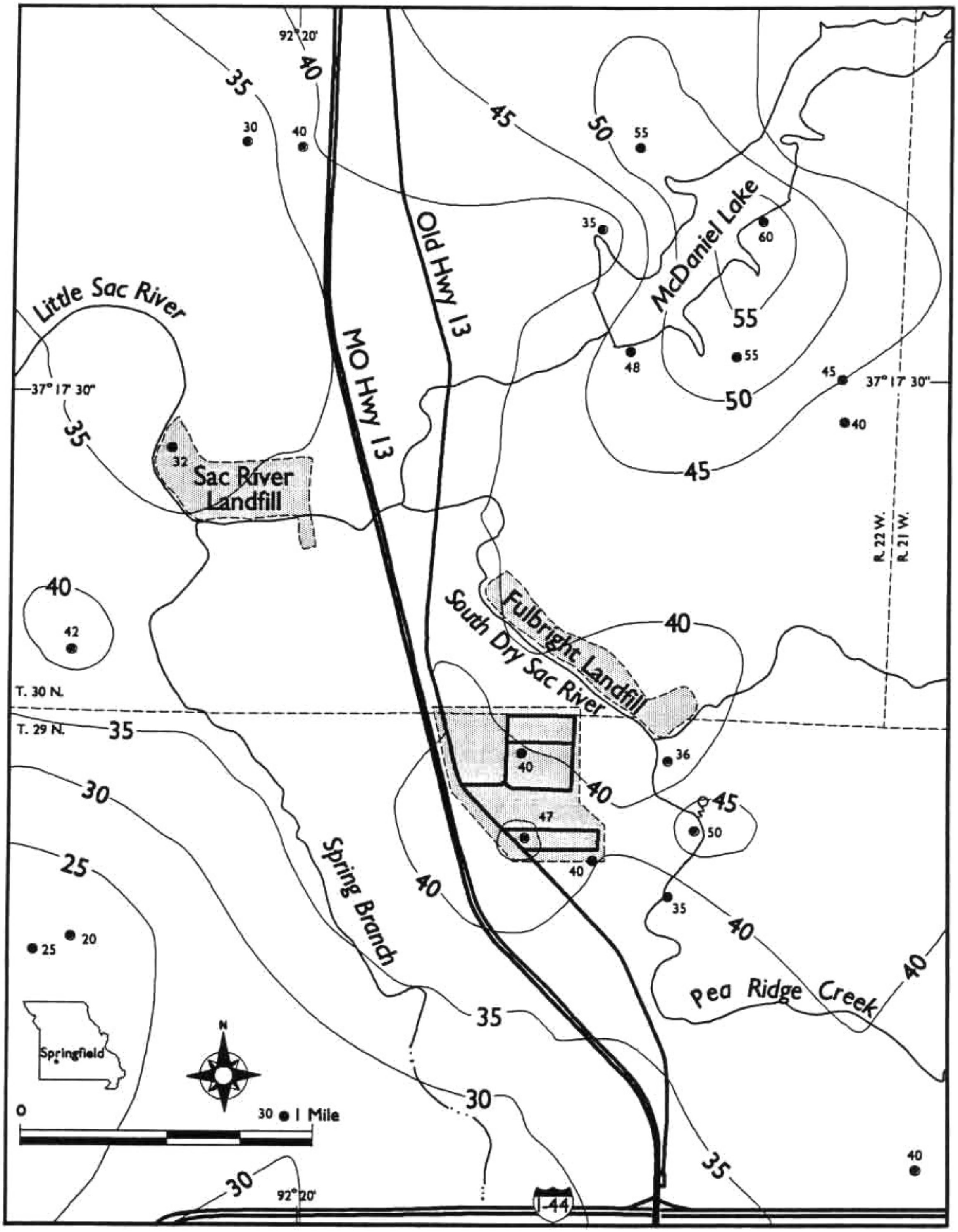

Figure 4. *Isopach map showing thickness of the Northview Formation, contour interval = 5 ft.*

Ozark aquifer consists of lower Ordovician and upper Cambrian units between the base of the Compton Formation and the top of the Doerun Dolomite. It consists, in descending order, of the Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconade Dolomite, Eminence Dolomite, and Potosi Dolomite. In much of the Springfield Plateau area, including the Fulbright area, it is a confined aquifer with a saturated thickness of about 1,200 ft. Saturated thickness decreases a few miles to the south of the study area in the center of Springfield where groundwater withdrawals have lowered the potentiometric surface of the Ozark aquifer to below the Ozark confining unit. The aquifer is fully saturated in the Fulbright area except when Fulbright well #1 is in operation. Then, the potentiometric surface of the aquifer near well #1 declines below the base of the Springfield confining unit.

Yields of wells fully penetrating the Ozark aquifer typically average 1,000 gpm in the Springfield area. Specific zones in the aquifer, however, are much more productive than others. Wells producing from the Jefferson City and Cotter dolomites typically yield less than 50 gpm. The highest producing zones are in the Roubidoux Formation, Lower Gasconade Dolomite, Gunter Sandstone member, Eminence Dolomite, and Potosi Dolomite. Immes and Emmett (in press) estimate the lateral hydraulic conductivity of the Ozark aquifer to be from 8.0×10^{-5} ft/sec (6.9 ft/day or 51.7 gpm/ft^2) to 1.3×10^{-4} ft/sec (11.3 ft/day or 84.0 gpd/ft^2). Assuming a saturated thickness of 1,200 ft, this equates to a transmissivity of between 13,560 ft^2/day (101,422 gpd/ft) and 8,280 ft^2/day (61,900 gpd/ft).

GROUNDWATER-LEVEL FLUCTUATIONS AND TRENDS IN THE FULBRIGHT AREA

A major component of this investigation is to better define the hydrologic characteristics and relationships of the Springfield Plateau and Ozark aquifers in the Fulbright areas. A network of 16 groundwater-level monitoring wells was established to quantify water-level fluctuations in the study area, and to help determine the factors which affect the configuration of the potentiometric surface. Locations of the wells are shown in figure 5.

It was beyond the scope of this study to construct dedicated monitoring wells to be used for water-level measurements, so existing wells had to be located and, where necessary, modified to allow water levels to be measured. The wells varied greatly in age, total depth, and quality of construction. Most of the wells used as monitoring wells during this study were originally drilled as private or public water supply wells. All of them are bedrock wells, and produce from competent rock. Well screens are not typically used in settings such as this because there are few problems with drill-hole stability. Only one well, North U Drive shallow monitoring well, contains well screen. Badly weathered rock necessitated using well screen to keep the hole from collapsing (Ecology and Environment, 1992). Also, it is the only well monitored which contains plastic casing. The remaining wells contain steel casing, and have open holes below the casing.

The casing depths of the Springfield Plateau aquifer wells are all quite shallow, and most do not appear to be pressure grouted. Since they are drilled into a shallow, unconfined aquifer, the quality of the casing and whether it is fully grouted has little impact on water-level measurements. The same does not hold true, however, for the Ozark aquifer wells. Here, the length of the casing, as well as how the casing is sealed, has a much greater effect on water-level measurements. Water levels measured from wells containing pressure-grouted casing set completely through the Northview Formation reflect the pressure head of the confined Ozark aquifer. Wells drilled into the Ozark aquifer that are either not cased through the Northview Formation, or contain casing that is not pressure grouted, may have water levels that are an "average" of the two aquifers.

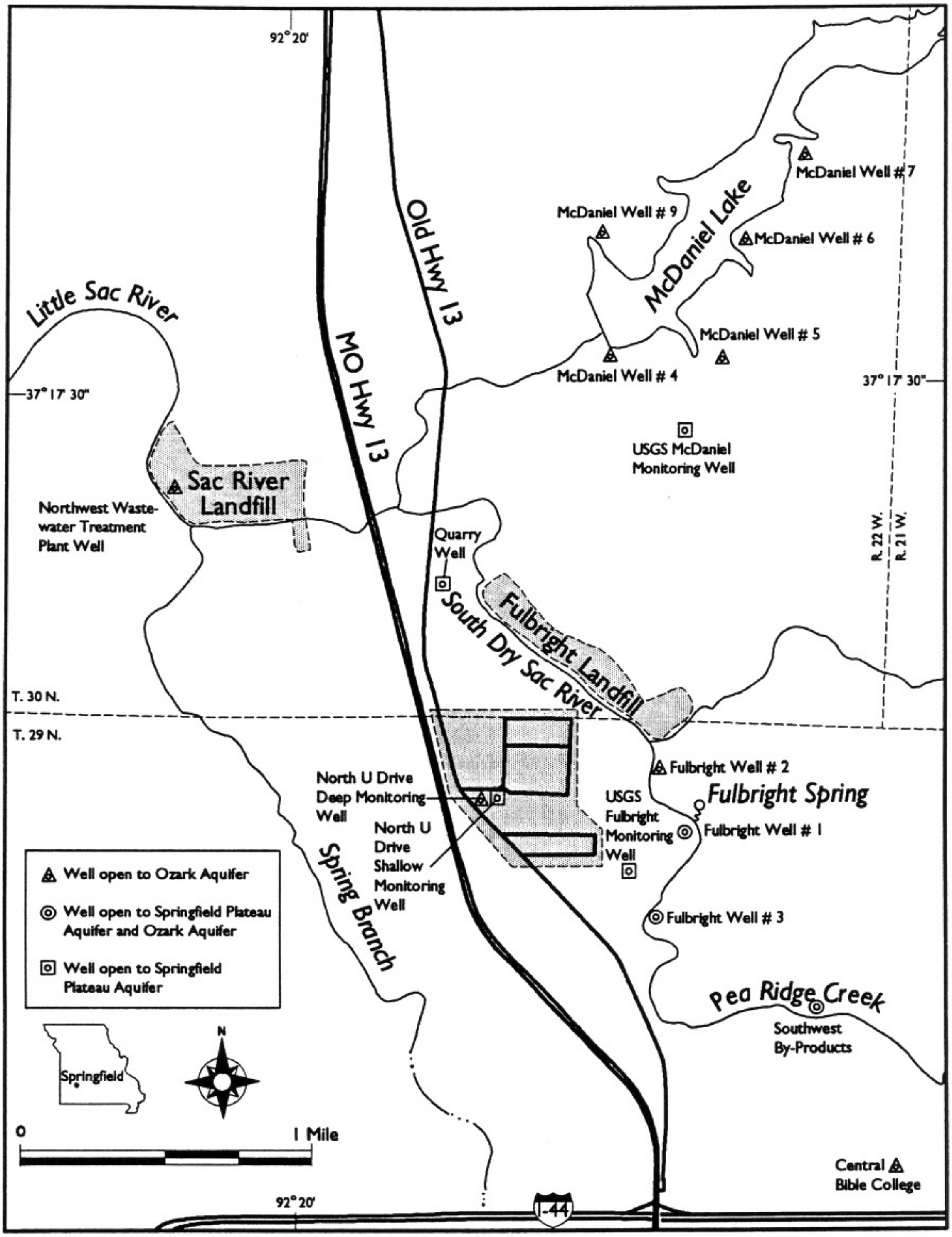

Figure 5. *Names and locations of wells monitored during this study.*

The monitoring well network established for this study consists of four wells open only to the Springfield Plateau aquifer. In this report these wells are referred to as the Quarry well, North U Drive shallow well, USGS Fulbright well, and USGS McDaniel Lake well. The remaining 12 wells penetrate varying thicknesses of the Ozark aquifer. Eight of these wells fully penetrate the Ozark aquifer, but of the eight, only six contain adequate lengths of pressure-grouted casing to exclude water from the Springfield Plateau aquifer. The six tightly cased, fully-penetrating Ozark aquifer wells are Fulbright well #2, and McDaniel Lake wells #4, #5, #6, #7, and #9. The two fully-penetrating wells that are not fully cased and grouted through the Northview Formation are Fulbright wells #1 and #3. Of the remaining four wells that partially-penetrate the Ozark aquifer, three contain pressure-grouted casing set through the Northview Formation. These are Central Bible College well #2, North U Drive deep monitoring well, and Northwest Wastewater Treatment Plant well. The remaining partially-penetrating Ozark aquifer well is Southwest By-Products well, which is cased through the Northview Formation, but is not pressure grouted.

It is difficult to estimate how much the inadequate casing affects water-level measurements in the wells that are either not cased through the Northview Formation, or that contain casing that was not pressure grouted. Because the water level in the Springfield Plateau aquifer is above that of the Ozark Plateau aquifer in the Fulbright area, water is probably draining from the shallow aquifer into the deeper aquifer through the unsealed portion of the well. This is likely to result in a water-level measurement somewhat above that which would be found in a tightly cased well. The amount of error this introduces is not known, but probably it is not more than a few feet, and possibly much less.

Water levels were measured three different ways. Two Ozark aquifer wells and two Springfield Plateau aquifer wells were equipped with digital water-level recorders that measure and record hourly water levels. Three of these installations were made by the Division of Geology and Land Survey. Recorders were installed on Fulbright wells #2 and #3, and on the Quarry well. The fourth recorder, which is owned and maintained by the USGS, is on the USGS Fulbright shallow monitoring well near Fulbright water treatment plant. The digital water-level recorders are capable of measuring and recording water-level changes of 0.01 ft.

Water levels at the five wells that do not contain pumps were measured using an electric water-level probe. Measurements were made approximately weekly using a Solinst water-level probe at Central Bible College well #2, Southwest By-Products well, North U Drive shallow and deep monitoring wells, and the USGS McDaniel Lake shallow monitoring well. Data collected in this manner should be accurate to within about 0.05 ft.

The remaining wells monitored throughout this study are owned by Springfield City Utilities or Springfield Department of Public Works, and are equipped with pumps. There are no provisions at these wells for measuring water levels with an electric probe, but the wells are equipped with air lines and pressure gauges to measure water level. The air line method uses a small-diameter air tube that extends from near the bottom of the pump column to a valve stem and pressure gauge at the surface. The air line is charged with compressed air of sufficiently high pressure to expel the water from the tube, and the pressure necessary to do so is measured by the gauge. The method measures the height of water above the bottom of the air line. So, if the length of air line is known, the water level can be calculated. All of the wells contained pressure gauges that were graduated in feet of water as well as pounds per square inch (psig). In theory, the air line method can yield fairly accurate water-level measurements. In practice, however, it is seldom as accurate as theoretically possible. The exact location of the bottom of the air line as reported by the pump installer may or may not be accurate. Air pressure gauges, especially those that have been outdoors and exposed to the elements for years, may yield measurements that are inaccurate. Water levels measured from air lines, especially those where the gauge accuracy and exact air line lengths cannot be verified, should be considered accurate only to within a few feet.

Accurate elevation data were not available for the most of the wells in the network, so a level and stadia rod were used to determine the elevation for each well. City of Springfield benchmarks were used for vertical control for most of the wells. A Missouri Highway Department benchmark was used for vertical control for the North U Drive wells. All elevations are based on the national geodetic vertical datum of 1929. Elevations at the McDaniel Lake wells were based on McDaniel Lake water-surface elevation.

Precipitation data were collected to help relate water-level fluctuations to rainfall events. The National Weather Service operates a weather station at Springfield Regional Airport about 5 miles southwest of Fulbright Landfill. Precipitation data are also collected by the Springfield Department of Public Works at the Northwest Wastewater Treatment Plant at the west end of the Sac River Landfill. To supplement these sources, a tipping bucket rain gauge and event recorder were installed between Fulbright wells #1 and #2. This installation collected data from April 1993 until December 1993. However, an intermittent problem with the event recorder resulted in lost data several times between September and December. Figure 6 shows precipitation data collected from these three sources.

Springfield Plateau Aquifer Water Levels

Water-level data were collected from four Springfield Plateau aquifer wells in the Fulbright area, two of which were equipped with digital water-level recorders. Data were collected from late March 1993 on three of the wells; the fourth is maintained by the USGS, and data is available from it since October, 1989.

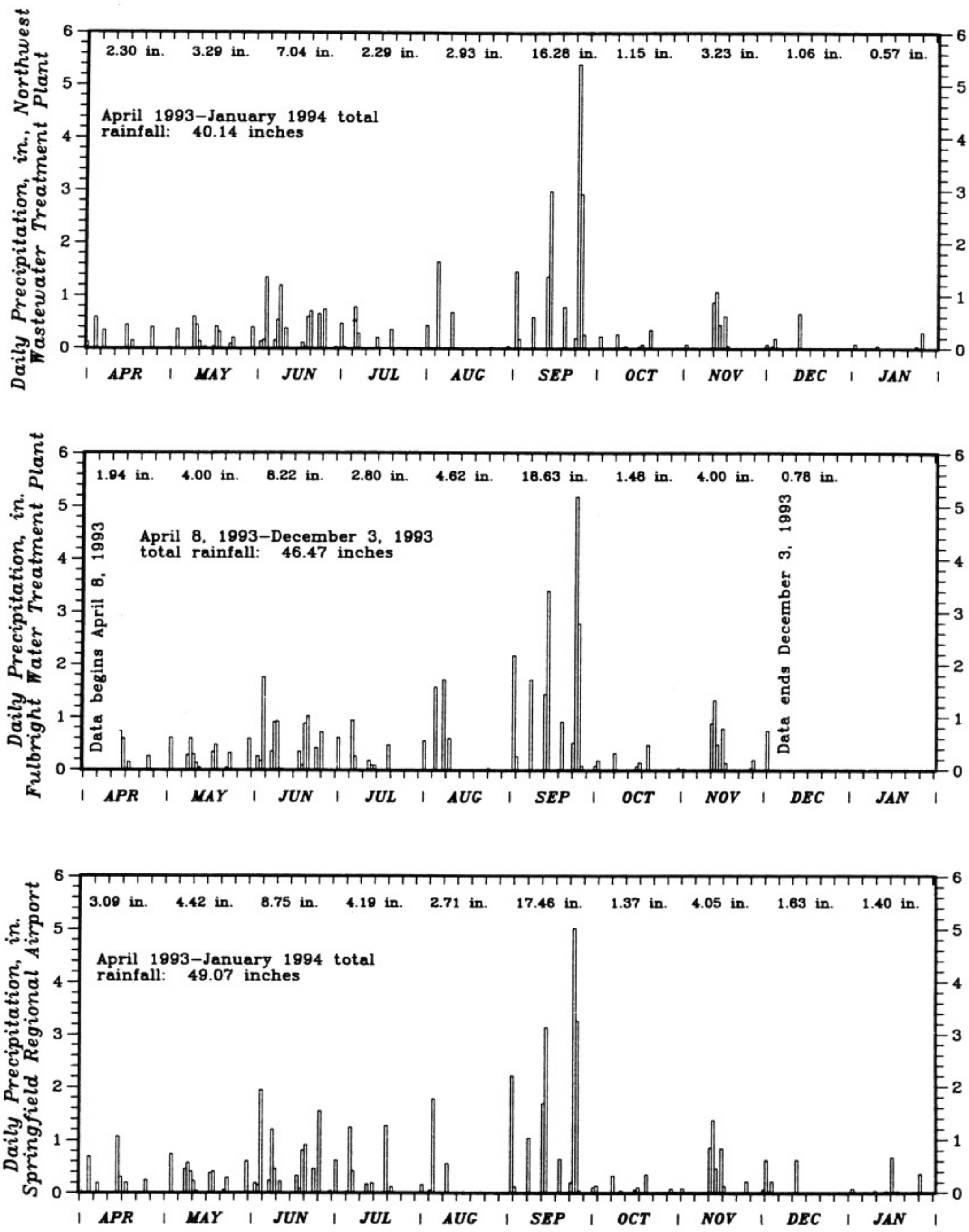

Figure 6. *Daily precipitation, April 1993 through January 1994, Springfield Regional Airport, Northwest Wastewater Treatment Plant, and Fulbright Water Treatment Plant.*

Between April 1993 and January 1994 water level in the USGS Fulbright monitoring well fluctuated from about 49 ft to 64 ft below the measuring point. Measuring point of the well is the base of the recorder box which is about 3 ft above land surface at an elevation of 1200.74 ft. Groundwater elevation varied from about 1151 ft to 1136 ft, a fluctuation of approximately 15 ft. Total fluctuation of the well since the recorder was installed in October 1989 is about 20 ft. Figure 7 shows hourly water-level data for the well for April 1993 to January 1994.

The Quarry monitoring well showed a similar pattern of water-level fluctuation. This well, which is at an elevation of 1132.10 ft, fluctuated from about 24 ft to 48 ft below the measuring point, which is 2 ft above ground surface. Groundwater elevation fluctuated from about 1108 ft to 1084 ft, a total of 24 ft (fig. 8).

The shallow monitoring well at North U Drive was not equipped with a recorder, but manual measurements showed a pattern similar to the Quarry and Fulbright shallow monitoring wells. Measuring point at this well is about 1 ft below land surface at an elevation of 1218.58. During the study, water level fluctuated from about 68.5 ft below measuring point to about 80.2 ft below measuring point, a total of 11.7 ft. Groundwater elevation varied from about 1150.1 ft to 1138.4 ft (fig. 9). However, since data were collected at this well at approximately 1 week intervals, total fluctuation was probably somewhat higher than that measured.

Water-level fluctuations at the USGS shallow monitoring well near McDaniel Lake differs greatly from the other three shallow monitoring wells. Water level in the McDaniel Lake well varied from about 79.8 ft to 80.3 ft below the measuring point. Elevation of the measuring point at the well is 1226.68, and is about 2 ft above ground level. Groundwater elevation varied from about 1146.9 ft to 1146.4 ft (fig. 10).

With the exception of the USGS well near McDaniel Lake, all of the Springfield Plateau aquifer wells monitored during this study showed rapid and pronounced water-level fluctuations in response to local rainfall. Figures 11 and 12 show daily precipitation measured at the National Weather Service station at Springfield Regional Airport plotted with hourly water-level hydrographs of the Quarry monitoring well and the USGS Fulbright shallow monitoring well. Depending on soil moisture storage, rainfall events of as little as 1 inch will cause measurable water-level rises. Water-level fluctuations at North U Drive shallow monitoring well are also obviously due to precipitation, but since data were collected at several day intervals, the relationship is less clear.

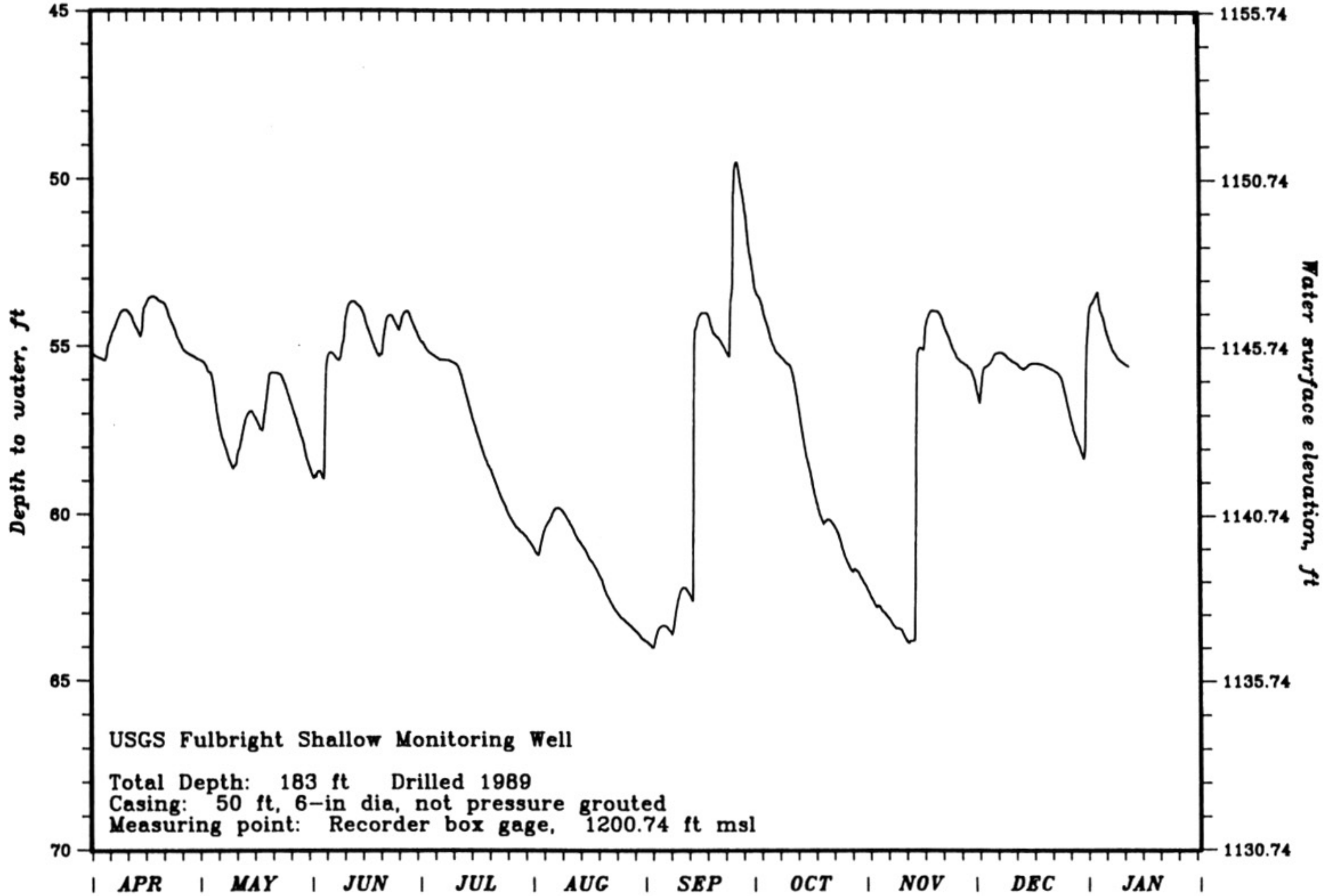

Figure 7. *Water-level hydrograph of the USGS Fulbright shallow monitoring well, April 1993 through January 1994.*

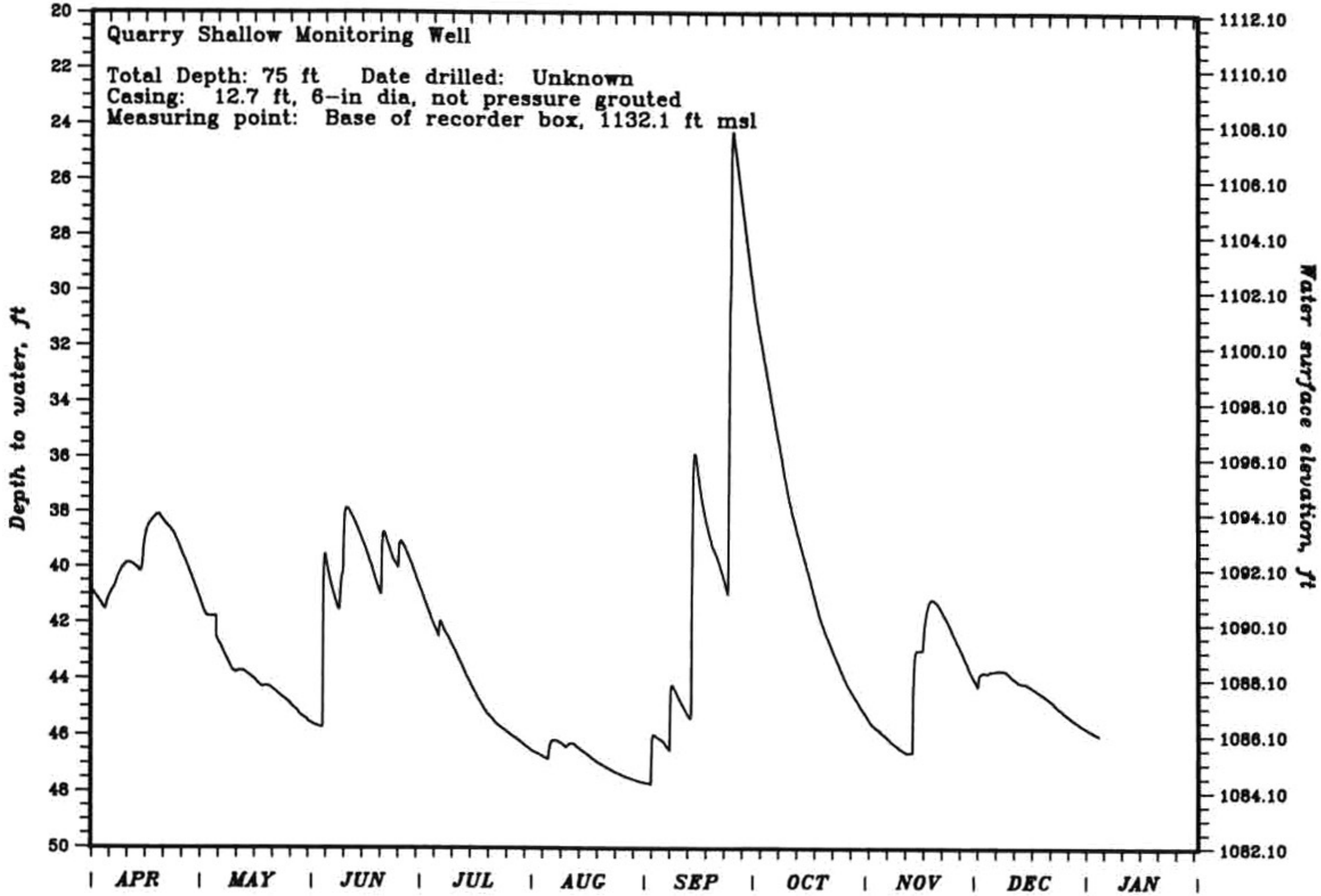

Figure 8. *Water-level hydrograph of the Quarry monitoring well, April 1993 through January 1994.*

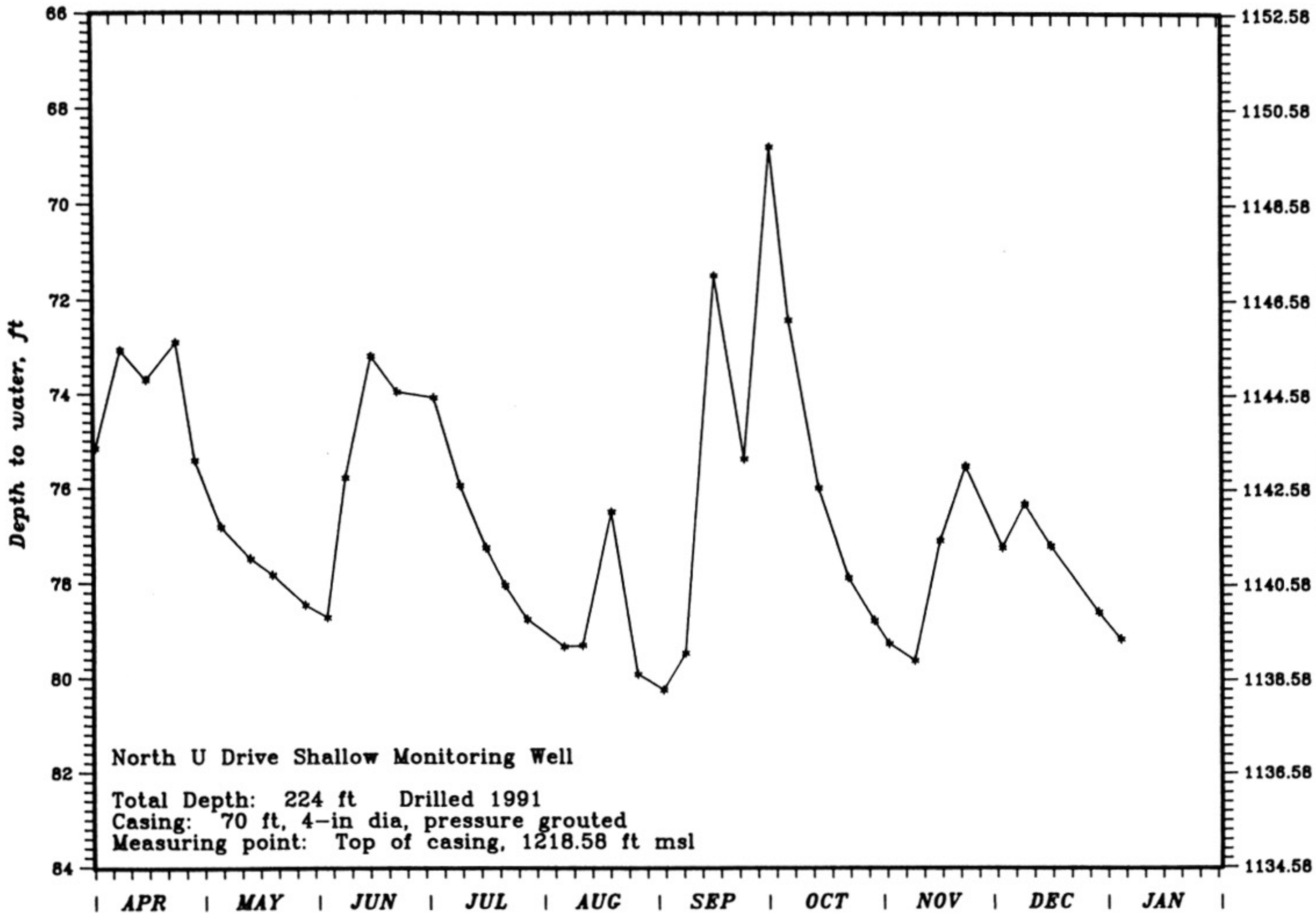

Figure 9. *Water-level hydrograph of the North U Drive shallow monitoring well, April 1993 through January 1994.*

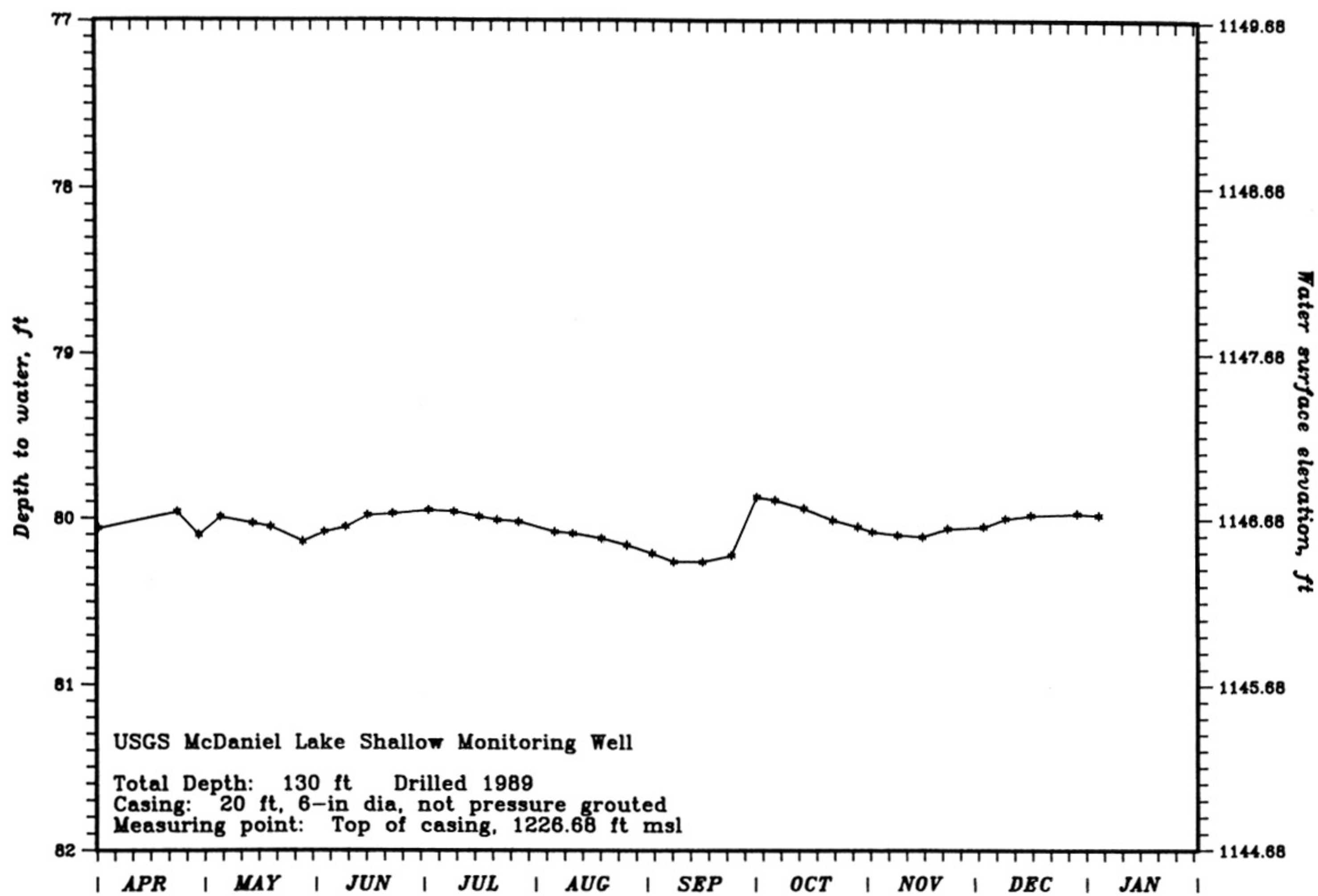

Figure 10. *Water-level hydrograph of the USGS McDaniel Lake shallow monitoring well, April 1993 through January 1994.*

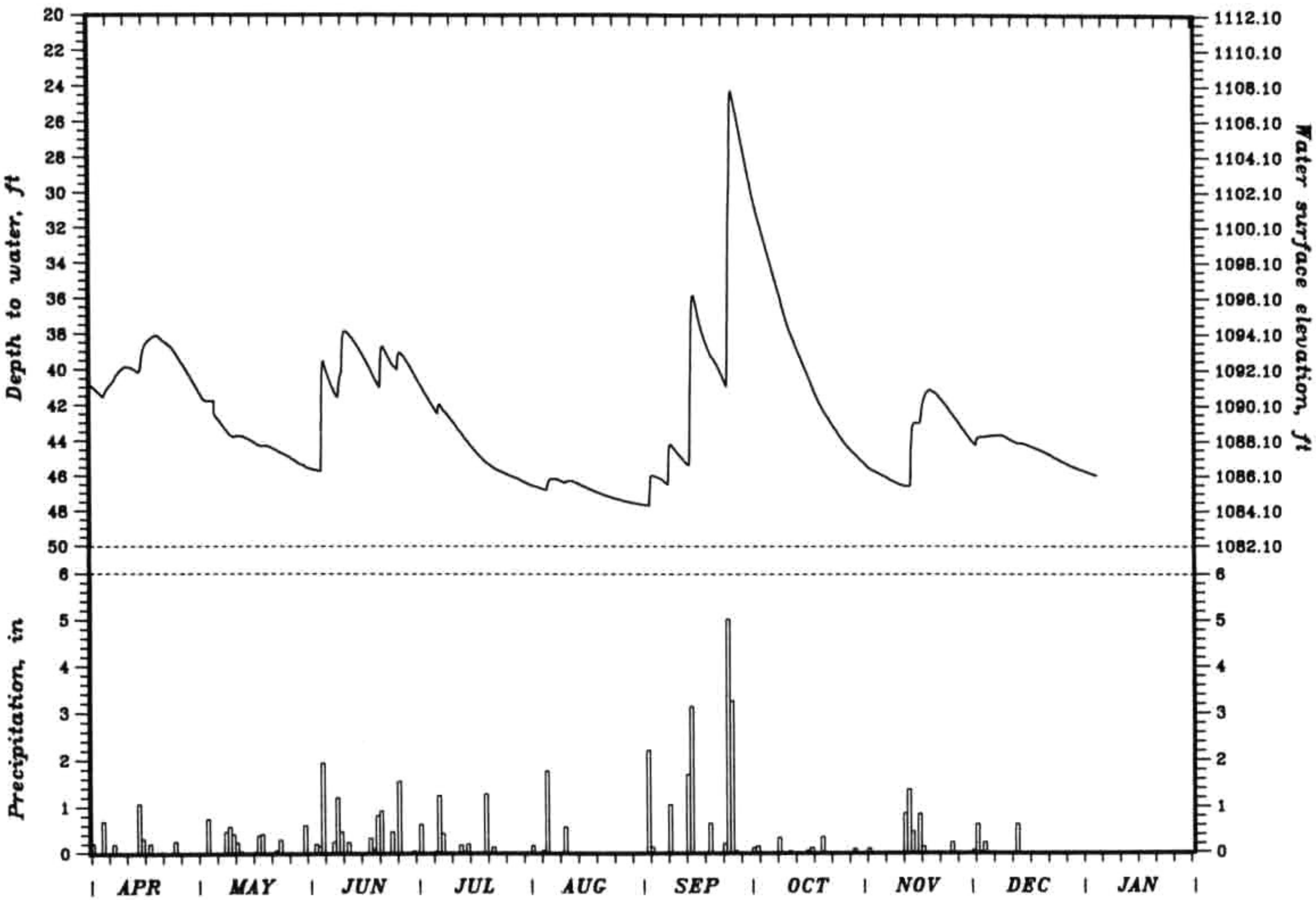

Figure 11. *The effects of precipitation on water level at the Quarry monitoring well.*

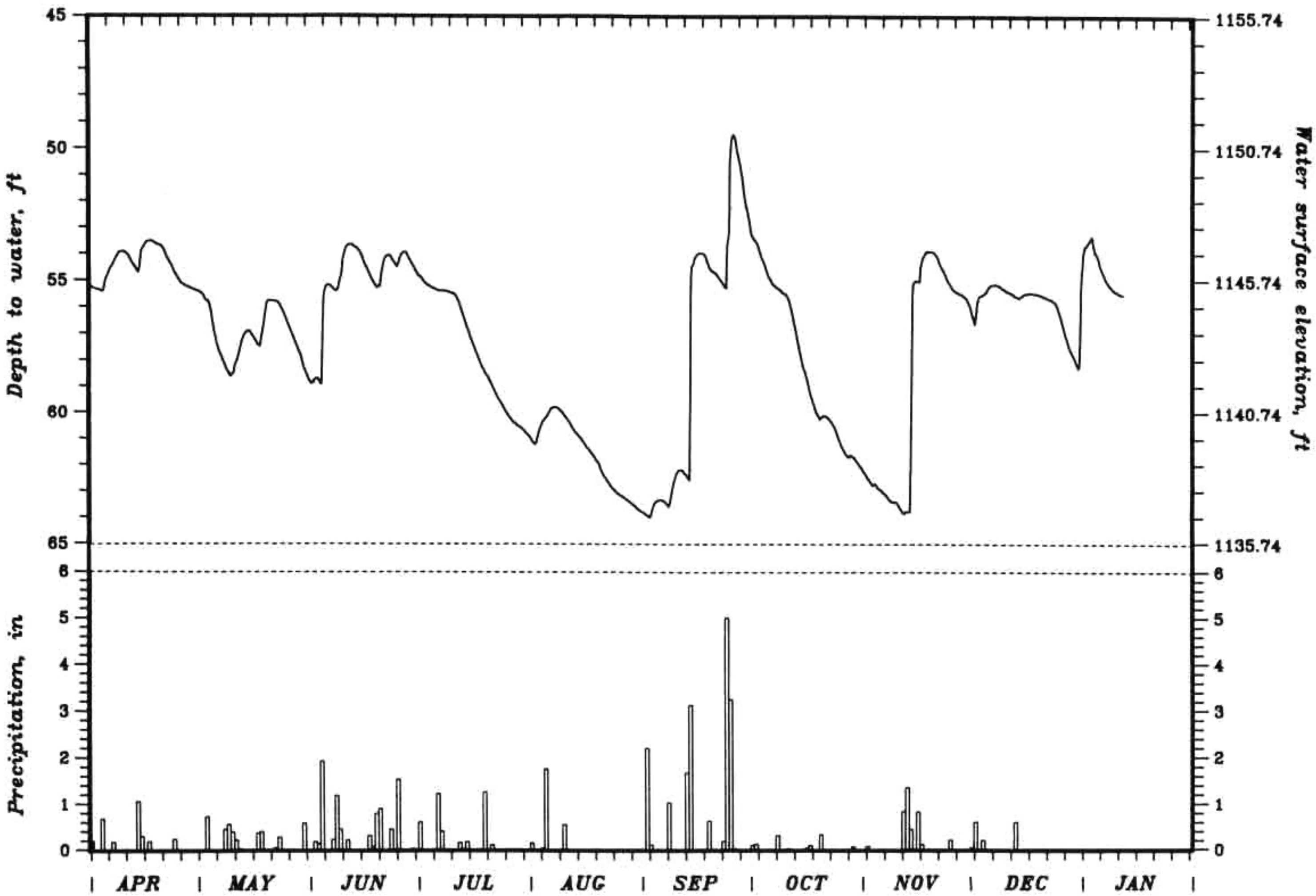

Figure 12. *The effects of precipitation on water level at the USGS Fulbright shallow monitoring well.*

Ozark Aquifer Water Levels

The Ozark aquifer monitoring wells also showed major water-level fluctuations, but the fluctuations were not due to precipitation. Ozark aquifer groundwater production, primarily at Fulbright well #1, caused the greatest water-level changes measured.

Because they were equipped with digital water-level recorders that collected hourly water-level data, Fulbright wells #2 and #3 showed water-level changes most accurately. At the first of April 1993, Fulbright well #2 had a static water level of about 61.8 ft below the base of the recorder box, or a water-surface elevation of 1046.4 ft (fig. 13). Water level depth decreased to about 53 ft (el 1055.2 ft) by mid-July. Well #1, which is 1,120 feet from well #2, was pumped twice for several hours in June. Both times, the water level in well #2 decreased 15 to 20 feet, but recovered within a few days after pumping ended. When Fulbright well #1 began pumping on August 2, depth to water in well #2 was 53.3 ft (el 1054.9 ft). Maximum depth to water occurred in late September at about 143.5 ft (el 964.7 ft). The pump in well #1 stopped twice in September due to electrical problems. Both times, water level recovered several feet before the pump was restarted. Drawdown after about 65 days of pumping was 90.2 ft. After well #1 stopped pumping on October 5, water level began recovering. By early January, depth to water had recovered to about 56 ft (el 1052.2 ft).

Well #3, which is 1,700 ft from well #1, showed a nearly identical pattern of water-level fluctuations (fig. 14). In early April, depth to water at well #3 was about 80 ft, or an elevation of about 1050.3 ft. Like well #2, water level rose several feet through May, June, and July, except for brief periods when well #1 was pumped. In late July, water level was about 72 ft (el 1058.1 ft). When pumping at well #1 started on August 2, water level was about 72.5 ft (el 1057.6 ft). By late September, water level had dropped to 176.3 ft (el 953.8 ft). Drawdown caused by well #1 was about 103.8 ft. Unlike well #2, which is tightly cased through the Northview Formation, well #3 contains only about 12 feet of casing, and is open to both the Springfield Plateau and Ozark aquifers. Despite this, water level in the well does not appear to respond to precipitation events.

The deep monitoring well at North U Drive, which is about 3,800 ft from well #1, showed a very similar pattern of water-level fluctuations, even through a recorder was not installed at the well (fig. 15). Depth to water at the well in early April was about 167.5 ft below top of casing (el 1051.4 ft). Depth to water generally decreased for the next four months, except for minor declines probably due to pumping well #1 in June. When pumping began at well #1 in August, depth to water at the North U Drive deep well was about 158.2 ft (el 1060.7 ft). Water level declined a total of about 68.8 ft to a depth of about 227 ft (el 991.9 ft). Water level began to recover when pumping of well #1 ended, and by early January 1994 was at a depth of about 164.3 ft (el 1054.6 ft).

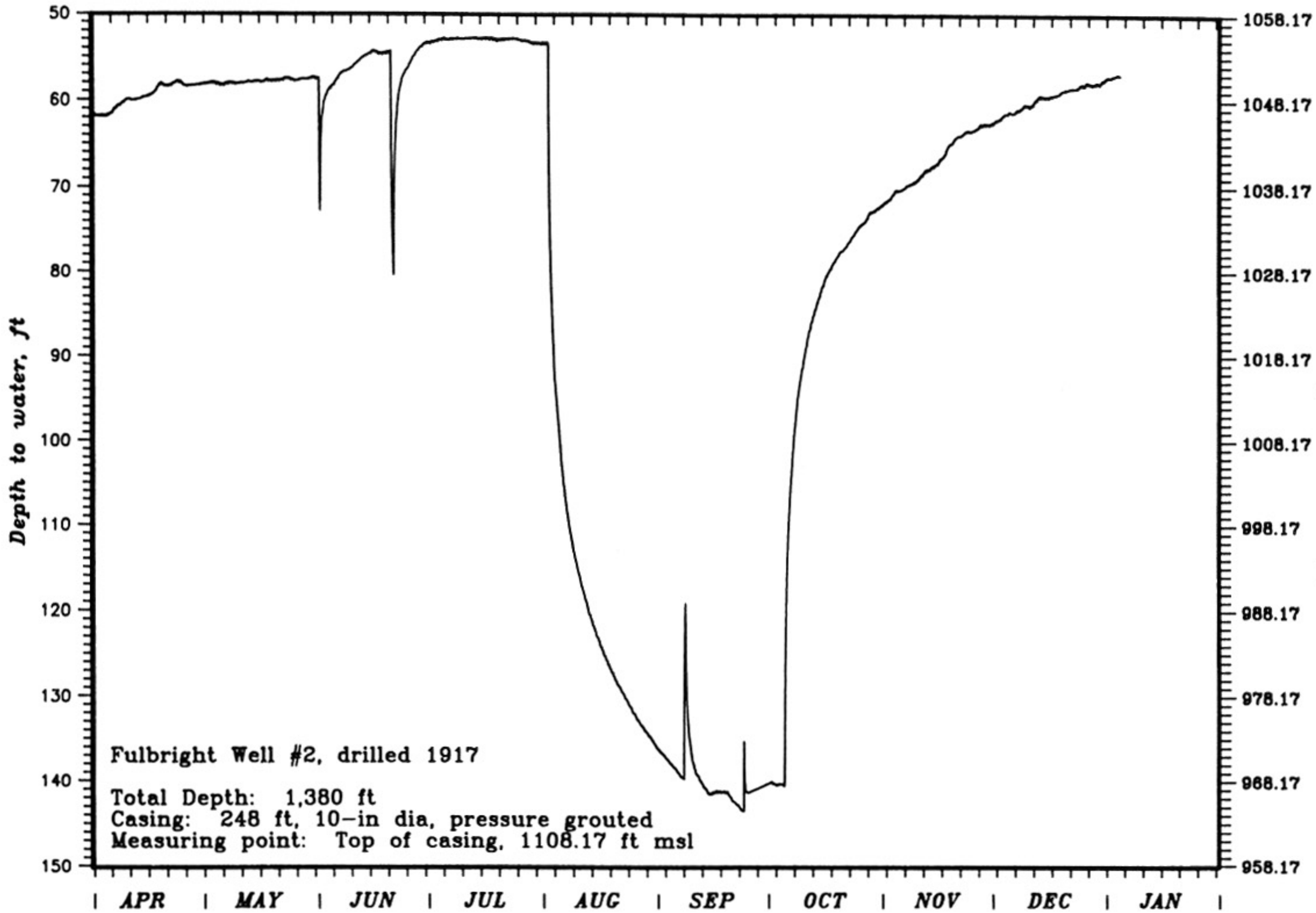

Figure 13. *Hourly water-level hydrograph of Fulbright well #2, April 1993 through January 1994.*

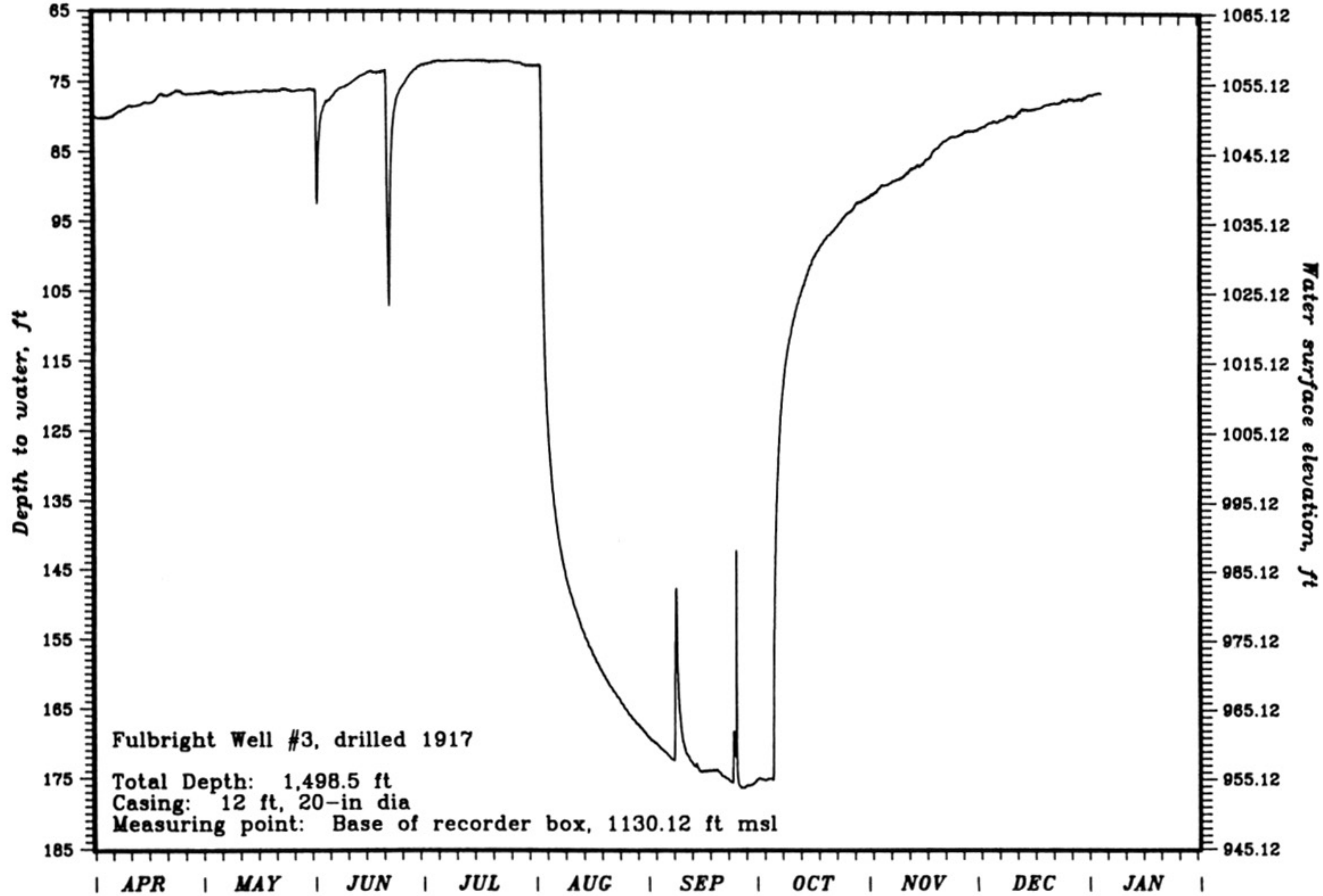

Figure 14. *Hourly water-level hydrograph of Fulbright well #3, April 1993 through January 1994.*

Water level in Fulbright well #1 showed the greatest fluctuation of the Ozark aquifer wells (fig. 16). At the first of April 1993, depth to water was about 75 ft (el 1038.5 ft). The depth to water generally decreased during the next four months to about 61 ft (el 1052.5 ft) when pumping began in early August. Water level quickly declined more than 300 ft to a maximum of 365 ft (el 748.5 ft) in early October. Water level recovered quickly once pumping ended, and by early January 1994, was about 68 ft (el 1045.5 ft).

Southwest By-Products monitoring well, which is about 4,200 ft southeast of well #1, also had a similar drawdown pattern, but appeared to have additional drawdown effects from one or more other pumping wells (fig. 18). This well is cased through the Northview Formation, but the casing is not thought to be pressure grouted. From the middle of April 1993 to early June 1993, water level declined from a depth of about 94.8 ft (el 1068.1 ft) to about 96.6 ft (el 1066.3 ft). From then until about July 9, water level rose to 89.8 ft (el 1073.1 ft). Unlike the monitoring wells farther to the north, water level here began to decline nearly a month before pumping at well #1 began. This is thought to be due to pumping at a well or wells in the area south of Southwest By-Products. Maximum water level was measured September 16 at 120.8 ft (el 1042.1 ft). Water level recovered to 94.6 ft (el 1068.3 ft) by early January 1994. Drawdown effects caused by pumping well #1 are difficult to estimate, but are probably less than 20 feet.

Water levels measured at Central Bible College well #2, like Southwest By-Products well, showed drawdown effects from more than one well (fig. 18). This well is the southernmost well monitored during this project, and is about 7,200 ft from Fulbright well #1. Additionally, it is within the City of Springfield drawdown cone, which accounts for its relatively deep water level. In early April 1993, water level was about 294.7 ft (el 997.8 ft). The depth to water decreased for the next month, and was 288.5 ft (el 1004.0 ft) in mid-May. Water level declined about 4 ft through June, recovered through early July, and declined to a low of about 299.2 ft (el 993.3 ft) the first of September. Unlike the wells to the north, depth to water decreased through September, and on October 5, when pumping ended at Fulbright Well #1, water level in Central Bible College well #2 was essentially the same as it was when the pump was started at Fulbright well #1. Shallowest water level was measured in early January 1994, when it was 277.5 ft (el 985.0 ft).

The Northwest Wastewater Treatment Plant (NWTP) well is about 11,250 ft northwest of Fulbright well #1. The well contains a pump and is used to supply part of the water needs at the treatment plant. However, the well is pumped at a fairly low rate in comparison to its maximum yield. Drawdown after short pumping periods is minor, and water level recovers rapidly after the pump stops. Water-level data collected at this well showed some short-term fluctuations which may reflect pumping, or may be due to the data being collected using an air line and pressure gauge.

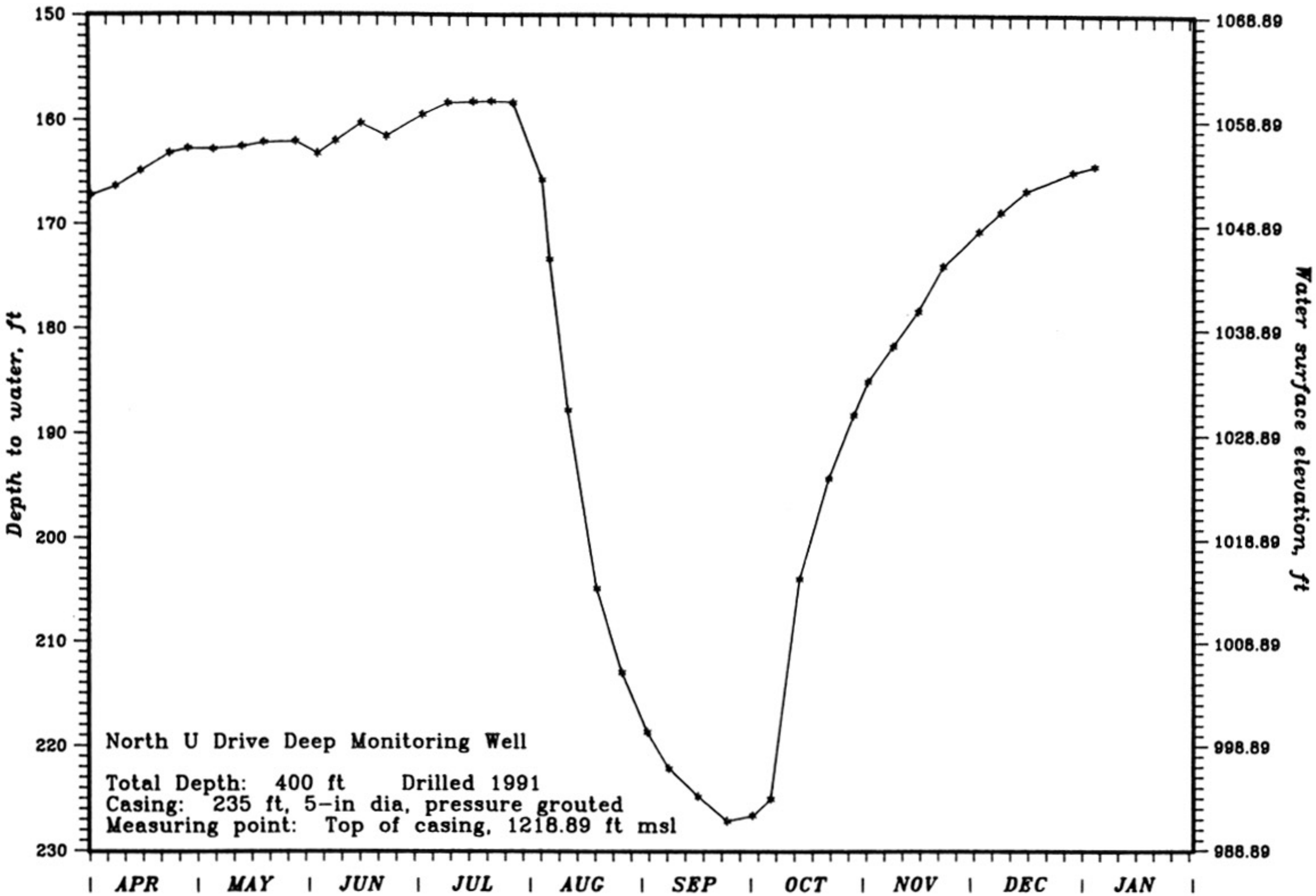

Figure 15. *Water-level hydrograph of the North U Drive deep monitoring well, April 1993 through January 1994.*

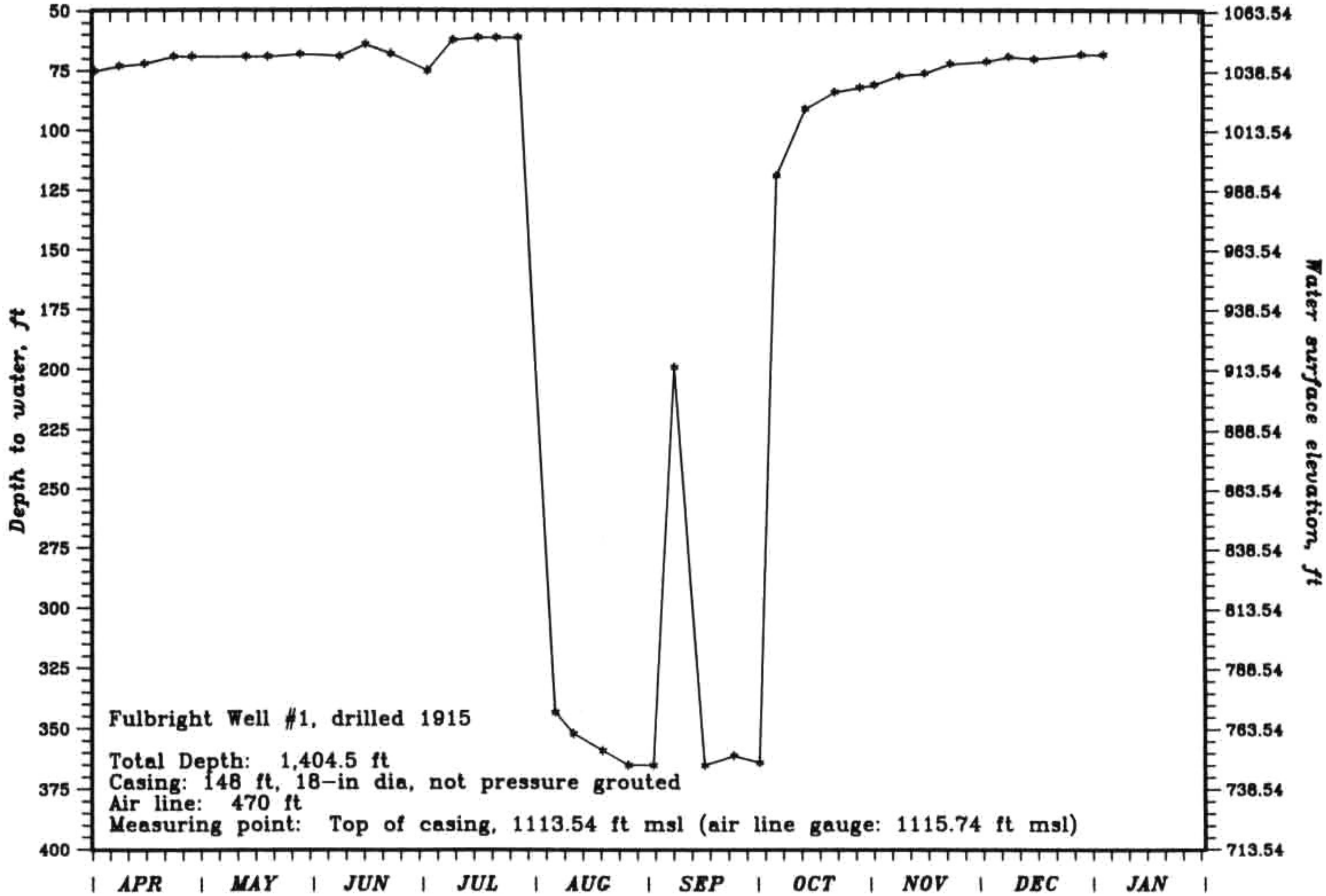

Figure 16. *Water-level hydrograph of Fulbright well #1, April 1993 through January 1994.*

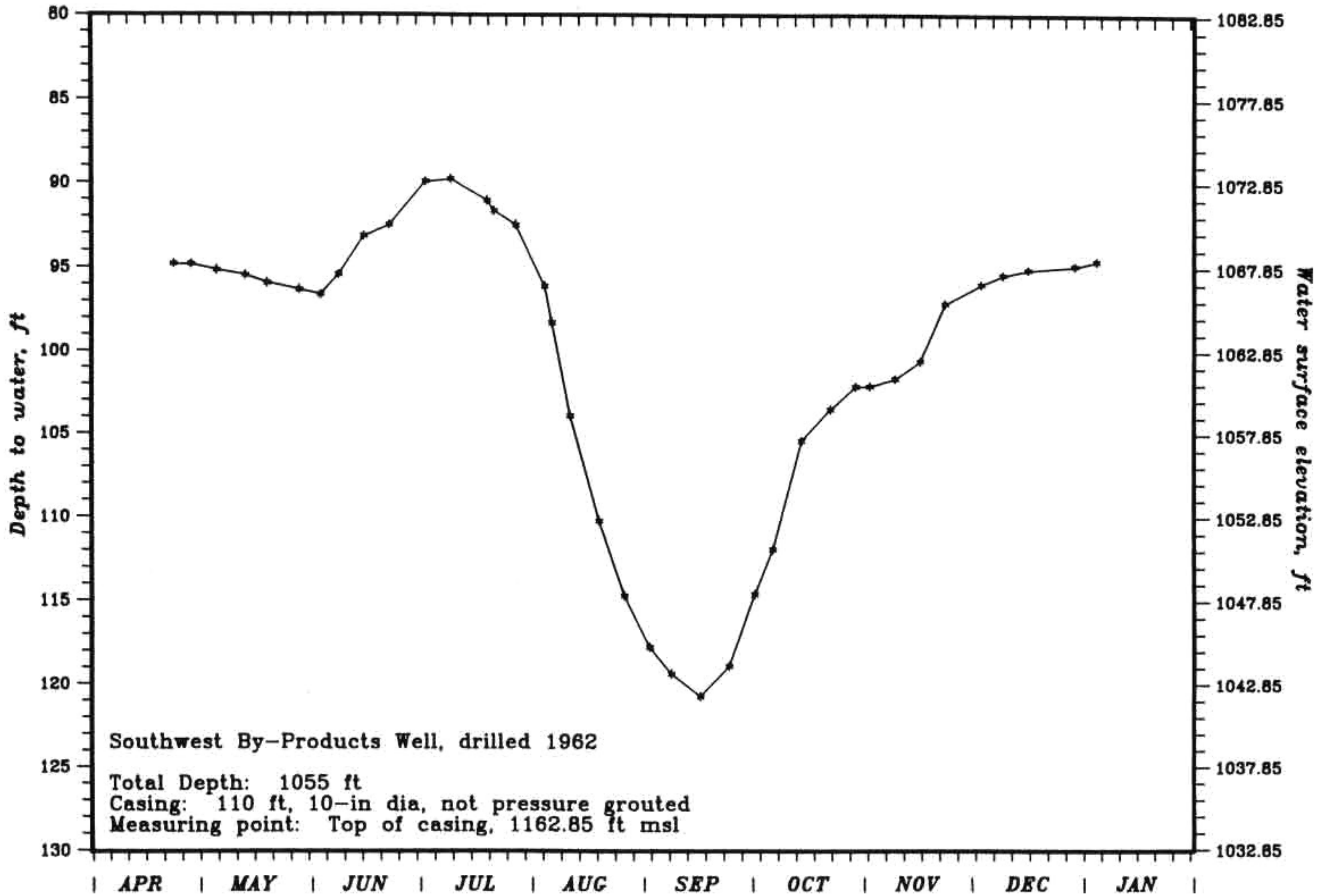

Figure 17. *Water-level hydrograph of the Southwest By-Products well, April 1993 through January 1994.*

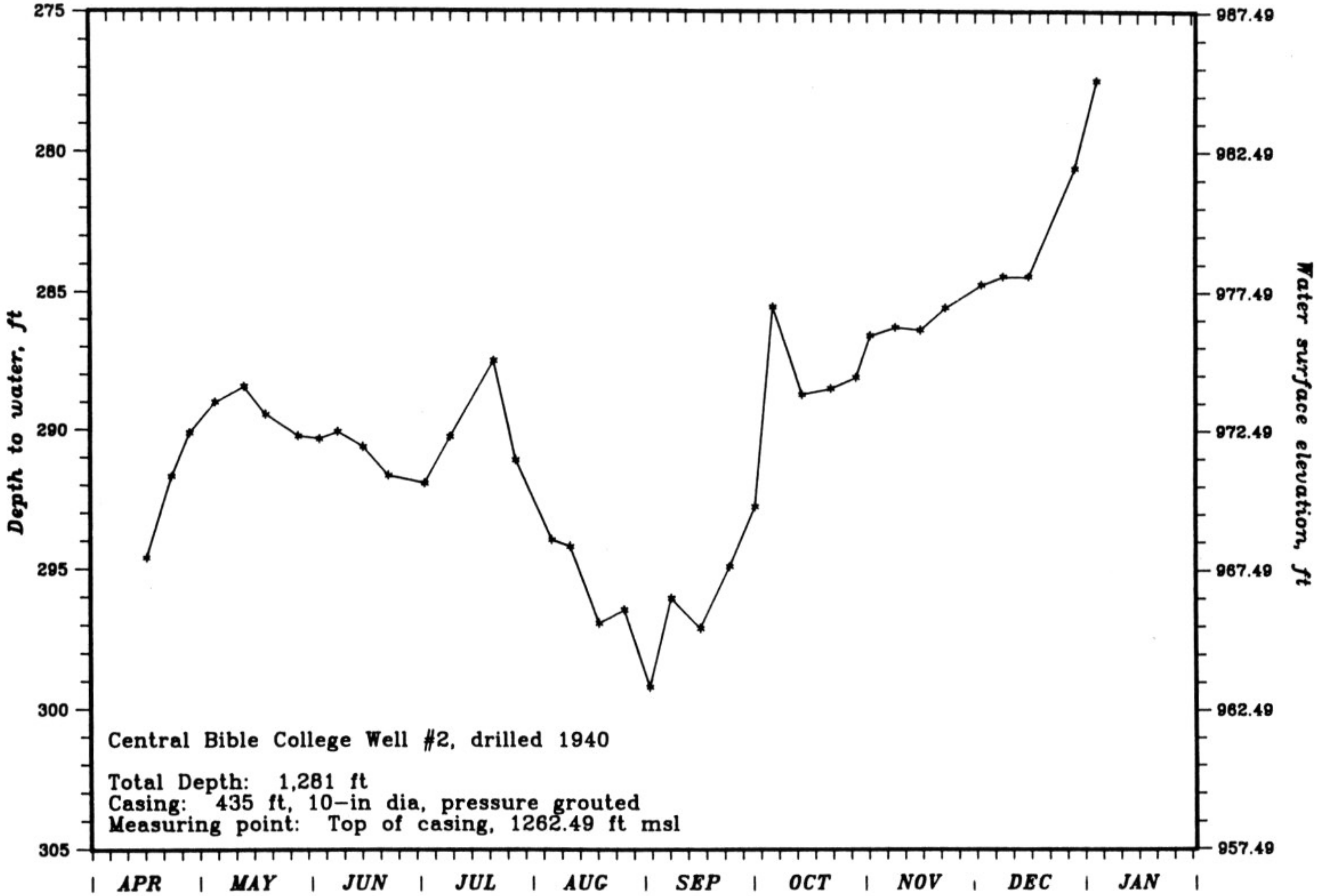

Figure 18. *Water-level hydrograph of Central Bible College well #2, April 1993 through January 1994.*

Water-level data collected using the air line and pressure gauge show relatively shallow water levels at this well. In early April 1993, the depth to water measured 27 ft (el 1054 ft). Water level generally decreased to the measured minimum of 13 ft (el 1068 ft) on July 9. It measured 17 ft (el 1064 ft) when pumping began at Fulbright well #1 in early August, and dropped to a maximum of 45 ft (el 1036 ft). When pumping ended October 5, depth to water measured 42 ft (el 1039 ft). Drawdown caused by pumping at well #1 was about 25 ft.

For obvious reasons, water-level measurements collected using air lines and pressure gauges are not nearly as accurate as those measured using an electric water-level probe or digital recorder. The greatest accuracy results when the exact vertical distance between the pressure gauge and the bottom of the air line is known, and by using an accurate pressure gauge. Each 1-ft error in the air line length causes 1 ft of error in the water-level measurement. Each pound per square inch (psig) error on the pressure gauge means a 2.31 ft error in water-level measurement. A portable 12-volt compressor was used for pressurizing the air lines during this study. To help determine the accuracy of the air line pressure gauges, a good-quality pressure gauge (reported accuracy of +/- 1 psig) was installed on the compressor to compare with the pressure readings of the air line gauges.

Figure 19 shows water-level data for the NWTP well. It is based on readings from the air line pressure gauge installed on the well. In comparing these values to those collected from the compressor pressure gauge, it appears that there may be from 3 ft to 13 ft of error in the air line gauge. Actual water levels may be from 3 ft to 13 ft lower than shown on figure 19.

There are five Springfield City Utilities production wells around McDaniel Lake that fully penetrate the Ozark aquifer. They are all tightly cased through the Northview Formation. Though not often used, these wells are all equipped with pumps. All of them are also equipped with air lines and pressure gauges. In this report, these will be referred to as McDaniel Lake wells #4, #5, #6, #7, and #9. These wells were all constructed in 1954 to help alleviate the possibility of water shortages during a major drought that was occurring at that time. Well #8 was plugged and abandoned before it was completed.

Figures 20 through 24 show hydrographs of the McDaniel Lake wells. They are based on water-level readings taken using the air lines and pressure gauges installed on the wells. With minor exceptions, the hydrographs are very similar. Depth to water decreased in all of the wells from early April 1993 through July 1993 when it reached the minimum depth for the year. Water levels at all of the wells declined through August and September 1993 in response to pumping at Fulbright well #1.

These wells are relatively closely spaced, and all are within a mile of each other. In early April 1993 when area groundwater production from the Ozark aquifer should

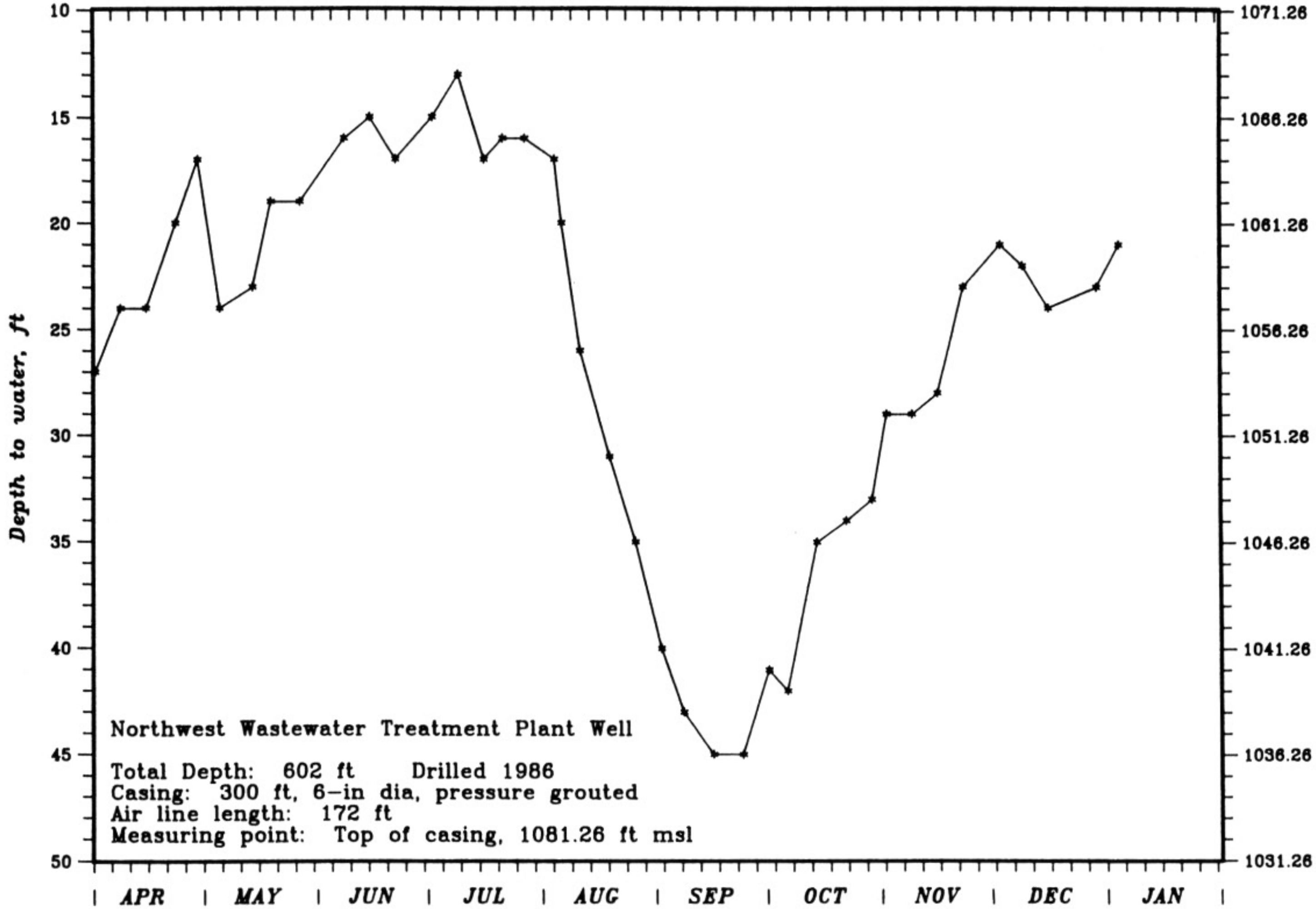

Figure 19. *Water-level hydrograph of the Northwest Wastewater Treatment Plant well, April 1993 through January 1994.*

be relatively low, water-level elevations at these wells should have been nearly equal. However, on April 1, there was 26 ft of water-level elevation difference between the wells based on measurements taken from the air lines and pressure gauges.

McDaniel Lake well #4 appears to have the most accurate data of the wells. The air line gauge generally varied only slightly from the compressor gauge, but actual water level may be up to 10 ft deeper than shown in figure 20. In early April 1993, the water level was about 94 feet below the gauge, or an elevation of about 1045. Minimum water level was in July 1993 at 70 ft (el 1069 ft). Maximum water level was measured in late September 1993 at 125 ft (el 1014 ft). Drawdown caused by pumping at Fulbright well #1, which is 8,600 ft south of well #4, was about 42 ft. By January 1994, water level had recovered to 89 ft (el 1050 ft).

The pressure gauge on McDaniel Lake well #5 appears to have the greatest error of the McDaniel Lake wells. Water levels measured here may actually be from 29 ft to 34 ft lower than shown on figure 21. Air line gauge data shows a depth to water of about 103 ft (el 1055 ft) in early April 1993. By late July, it had decreased to about 70 ft (el 1088 ft). Drawdown caused by well #1, which is 8,500 ft south of well #5, measured 48 ft. Water level in late September measured about 120 ft (el 1038 ft), and it recovered to about 80 ft (el 1078 ft) by January 1994.

Measured water level in McDaniel Lake well #6 in early April 1993 was 111 ft (el 1029 ft), and it decreased to 92 ft (el 1048 ft) by late July. In early October when well #1 ceased pumping, water level measured 135 ft (el 1005 ft). Well #6 is about 10,800 ft from well #1, and drawdown caused by 2 months of pumping at well #1 was about 43 ft. By early January 1994, water level had recovered to about 101 ft (el 1039 ft). Figure 22 shows water-level data collected at McDanield Lake well #6 using the air line and pressure gauge installed on the well. Based on the compressor gauge, there may be as much as 12 ft of error, and actual water levels may be about 12 ft lower than measured.

The hydrograph of McDaniel Lake well #7 is shown on figure 23. Measured water level in early April 1993 was 80 ft (el 1050 ft), and it decreased to 53 ft (el 1078 ft) by late July. When well #1 stopped pumping in early October, water level in well #7 measured 96 ft (el 1035 ft). Well #7 is about 12,400 ft from well #1, and drawdown measured 43 ft. By early January 1994, water level had recovered to about 67 ft (el 1064 ft). Compressor pressure gauge readings indicate that there may be 21 ft to 23 ft of error in water level measurements taken at well #7. Actual water level may be 21 ft to 23 ft lower than shown on figure 23.

Water-level measurements taken at McDaniel Lake well #9, and shown in figure 24, may also contain appreciable error. The air line gauge varied from the compressor gauge by 19 ft to 24 ft. Actual water level in the well may be 19 to 24 ft deeper than shown in figure 23. In early April 1993, measured water level was about 75 ft (el 1054

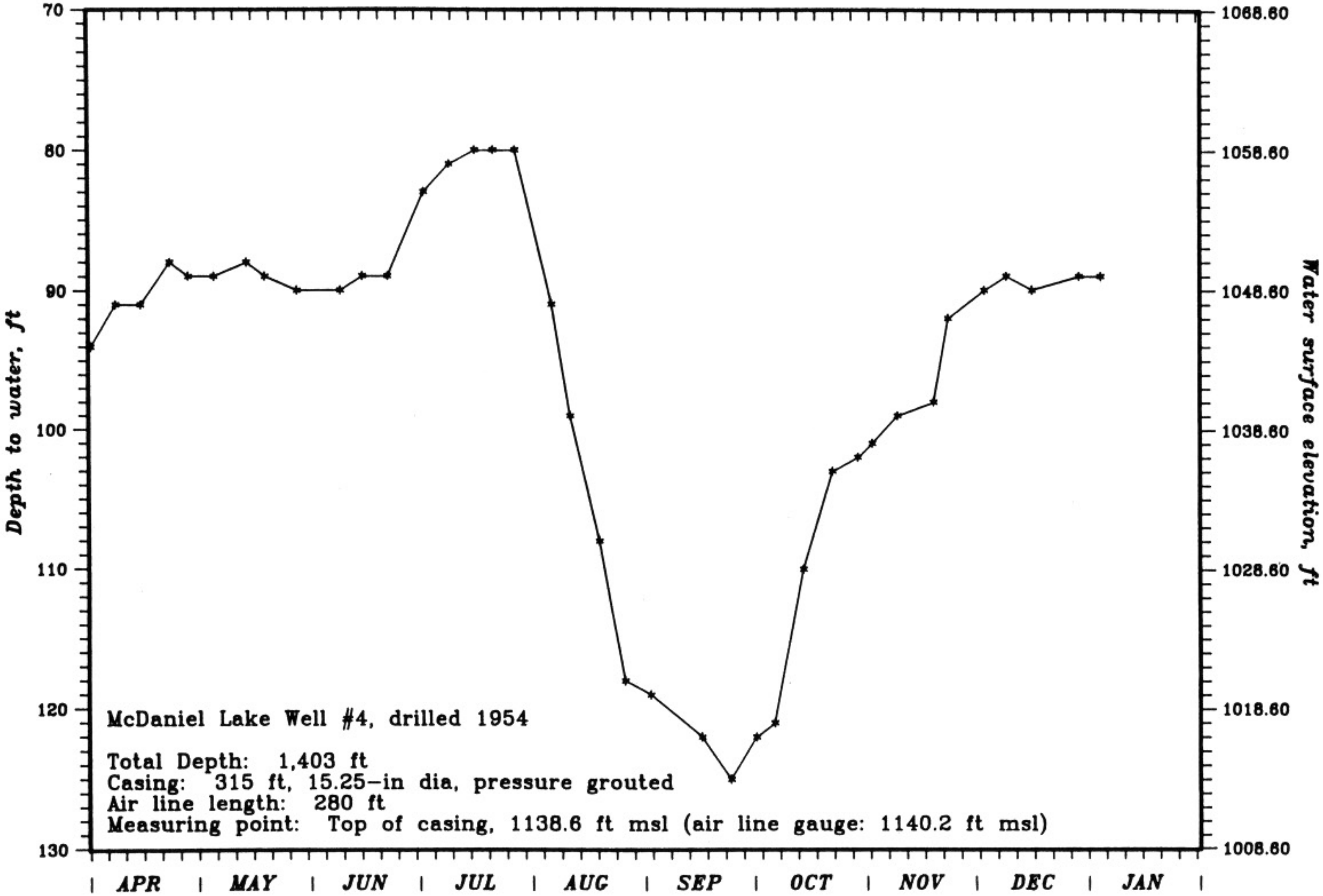

Figure 20. *Water-level hydrograph of McDaniel Lake well #4, April 1993 through January 1994.*

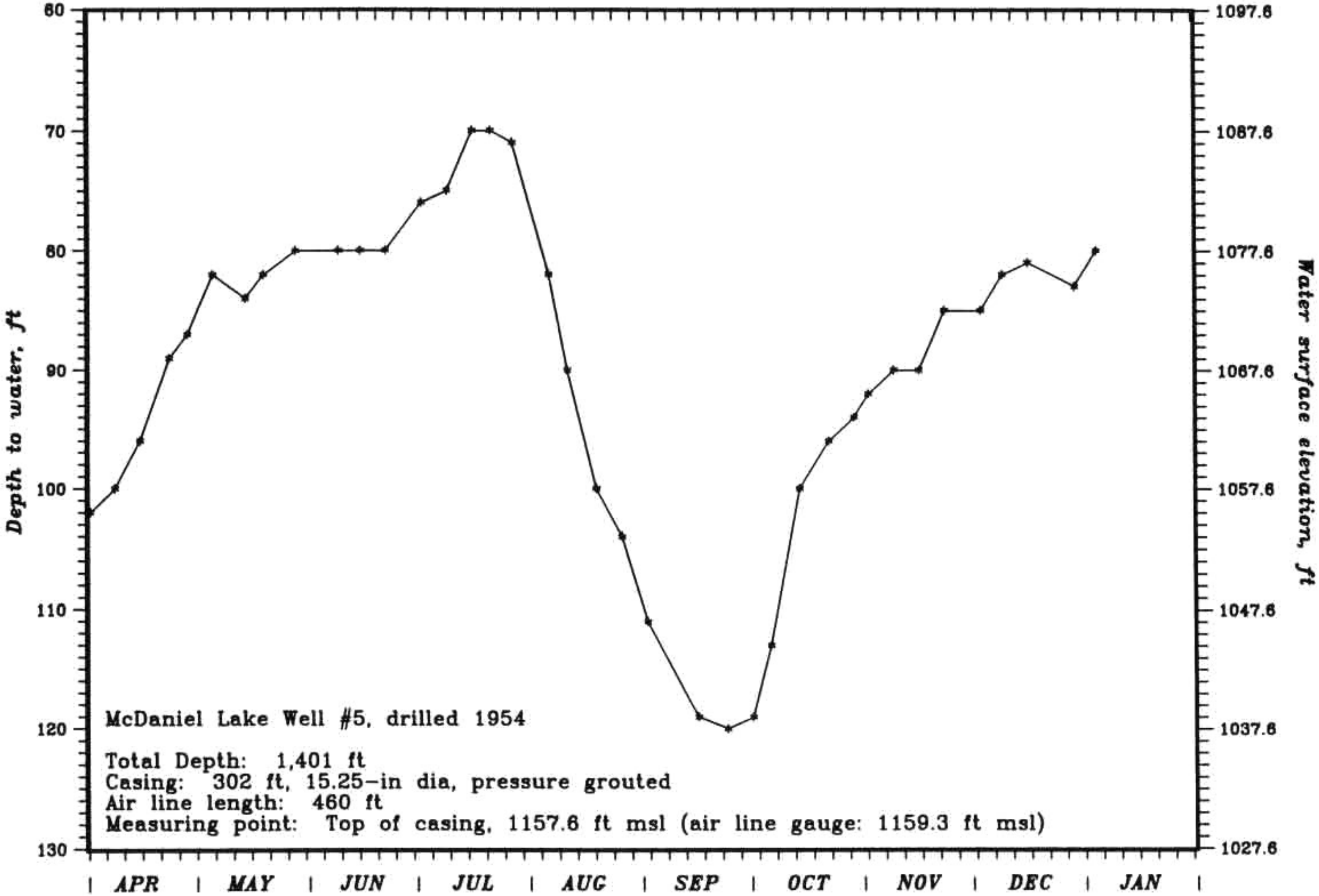

Figure 21. *Water-level hydrograph of McDaniel Lake well #5, April 1993 through January 1994.*

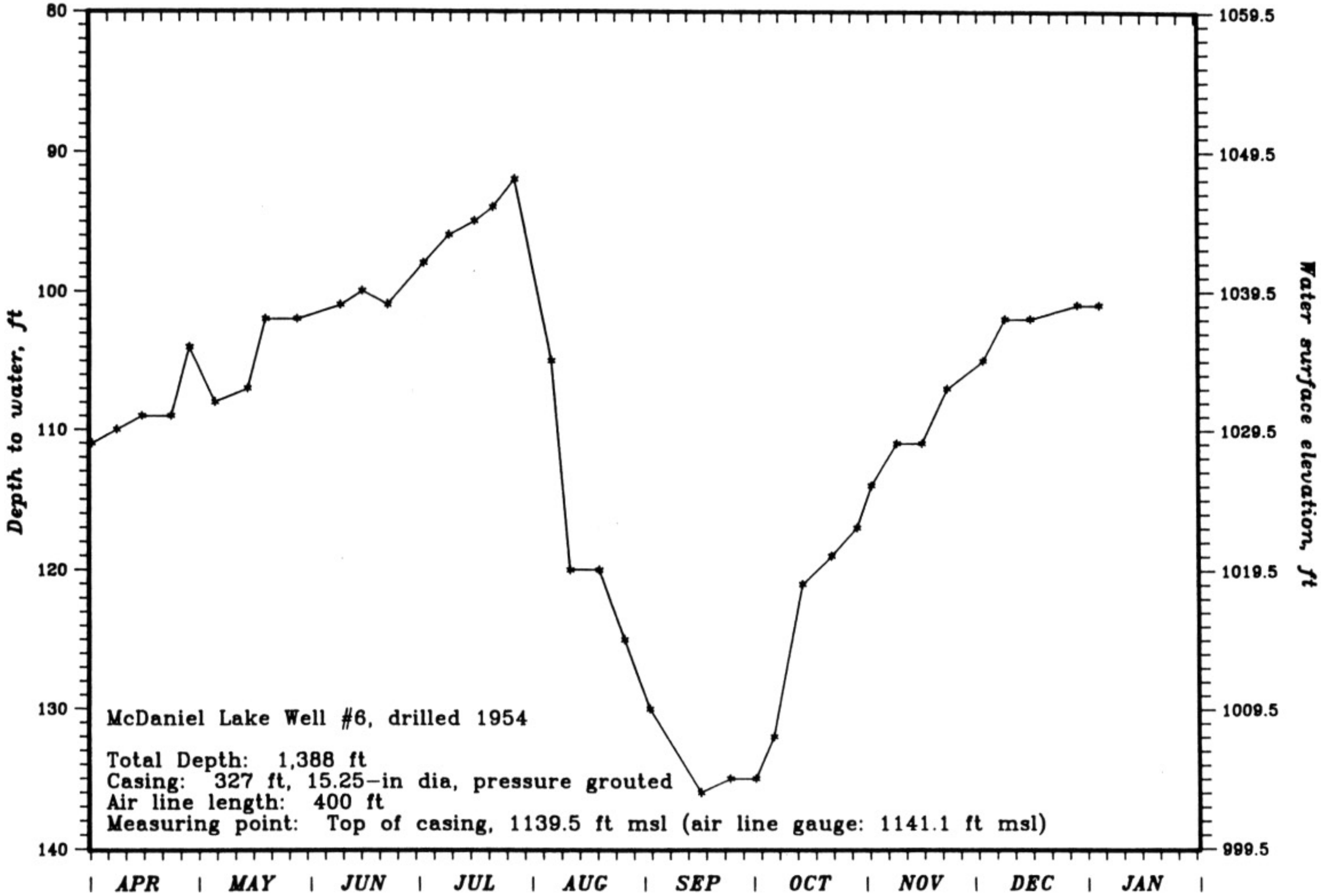

Figure 22. *Water-level hydrograph of McDaniel Lake well #6, April 1993 through January 1994.*

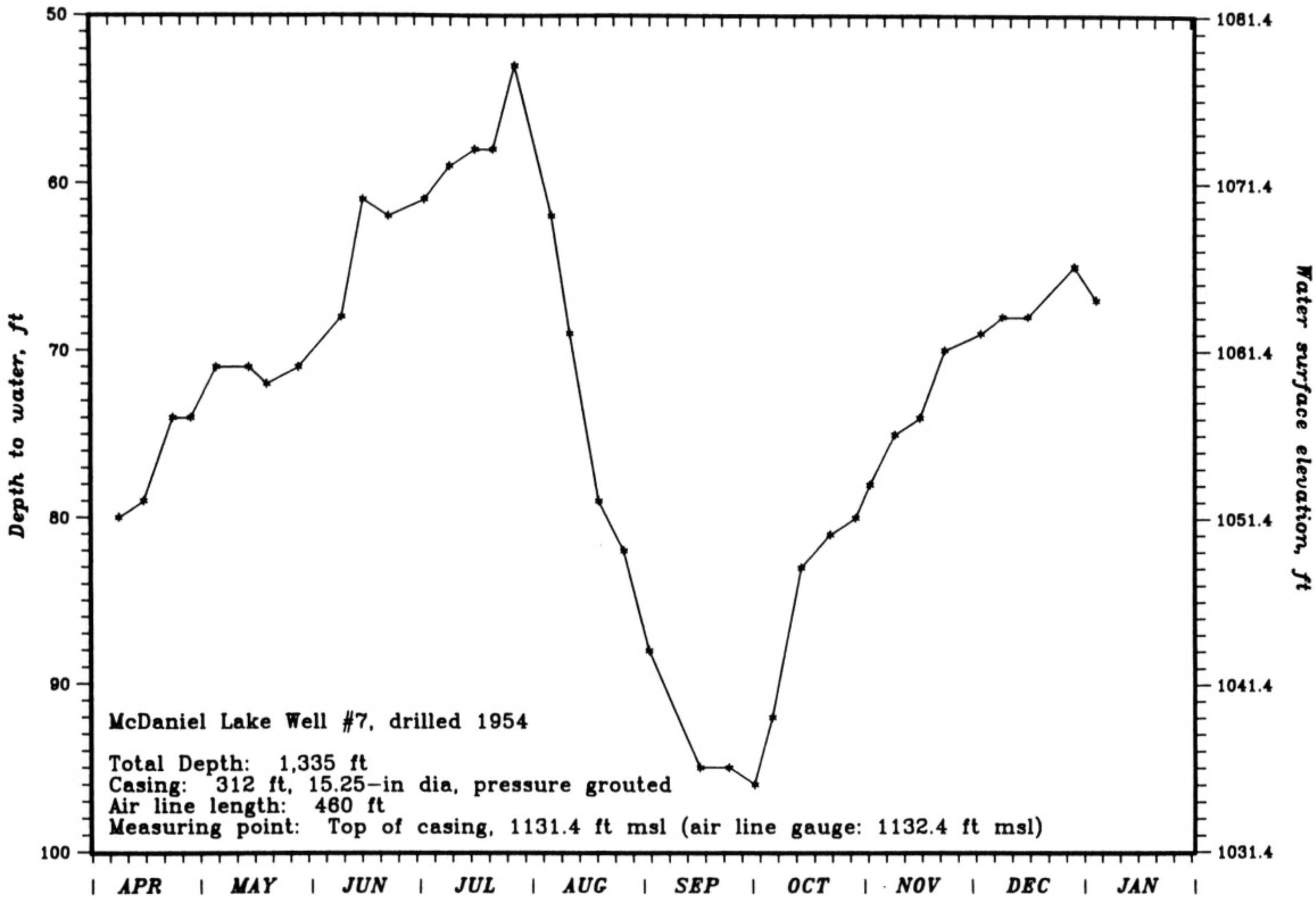

Figure 23. *Water-level hedrographic of McDaniel Lake Well #7, April 1993 through January 1994.*

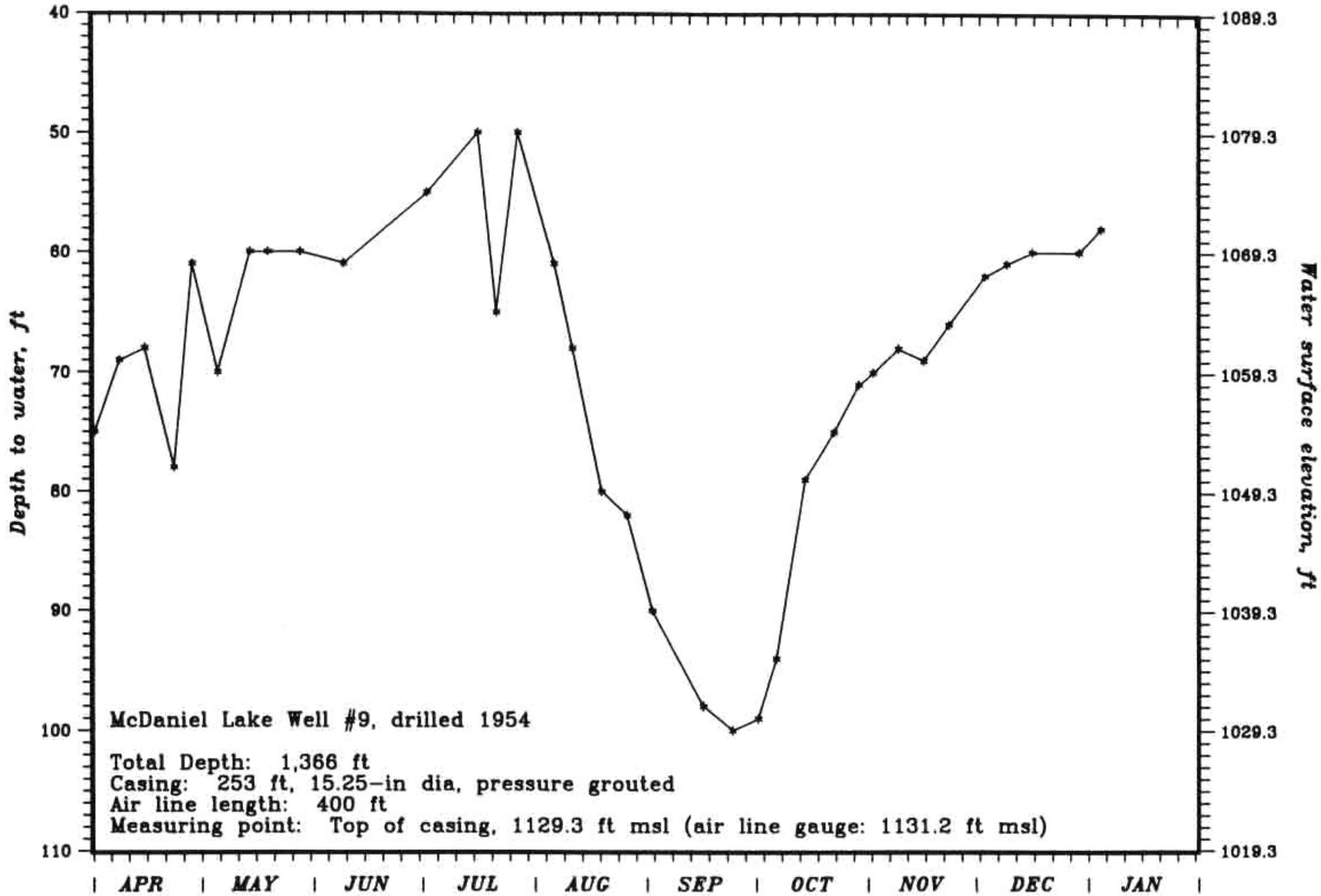

Figure 24. *Water-level hydrograph of McDaniel Lake well #9, April 1993 through January 1994.*

ft). It decreased to about 50 ft (el 1079 ft) by late July. Measured water level in early October was about 100 ft (el 1029 ft). Well #9 is about 10,900 ft from Fulbright well #1, and drawdown measured about 49 ft.

POTENTIOMETRIC SURFACE OF THE OZARK AQUIFER IN THE FULBRIGHT AREA

Water-level data collected during this study were used to construct two Ozark aquifer potentiometric maps. One map shows the potentiometric surface on June 15, 1993, before Fulbright well #1 began pumping (fig. 25). The second shows the potentiometric surface on October 1, 1993, after well #1 had been pumping for 2 months (fig. 26).

Figure 25, the pre-pumping potentiometric map, shows a groundwater divide south of Fulbright well #1 in the Southwest By-Products well area. Contour interval of this map is 5 ft. The divide likely extends west from Southwest By-Products, but could not be identified due to the lack of data in the southwest part of the study area. The potentiometric surface in the area between Fulbright Water Plant and the Northwest Wastewater Treatment Plant is relatively flat, with only a few feet of relief. As drawn, the potentiometric map shows groundwater movement toward Fulbright well #1 from the Northwest Wastewater Treatment Plant. However, this depends entirely on the accuracy of the data collected at the Northwest Wastewater Treatment Plant well. The value of 1056 ft is based on the compressor pressure gauge. An error of only 3 feet, which is entirely possible with the technique used to measure water level at this well, would show a reverse gradient from Fulbright well #1 to the northwest. Regardless of this, the data do show a low gradient in the Ozark aquifer in the area between Fulbright and the Northwest Wastewater Treatment Plant, and the gradient during non-pumping periods may be to the northwest or southeast.

The potentiometric surface after Fulbright well #1 has been pumping for two months is entirely different (fig. 26). Based on Springfield City Utilities information, well #1 will produce about 2,300 gpm when first started, and even after several months of pumping will produce more than 2,000 gpm. If not the highest, it is one of the highest yielding Ozark aquifer wells in Missouri. Production from similar wells is generally less than 1,200 gpm in the Springfield area. As seen from the water-level hydrographs of individual wells, there is considerable drawdown in the Ozark aquifer after well #1 has been pumping for two months. The October 1, 1993, potentiometric map, which has a contour interval of 20 ft, shows a cone-of-depression centered on well #1 extending outward in all directions. The groundwater divide south of Fulbright is still evident in the Southwest By-Products well area, but the potentiometric map shows an inward flow gradient toward Fulbright well #1 for most of the study area. Water-surface elevation in the Northwest Wastewater Treatment Plant area was about 1040 ft, and at Fulbright well #1 was about 754 ft. After well #1 has operated for any appreciable length of time, groundwater movement in the Ozark aquifer beneath the North U Drive site, Sac River Landfill, and Fulbright Landfill is toward well #1.

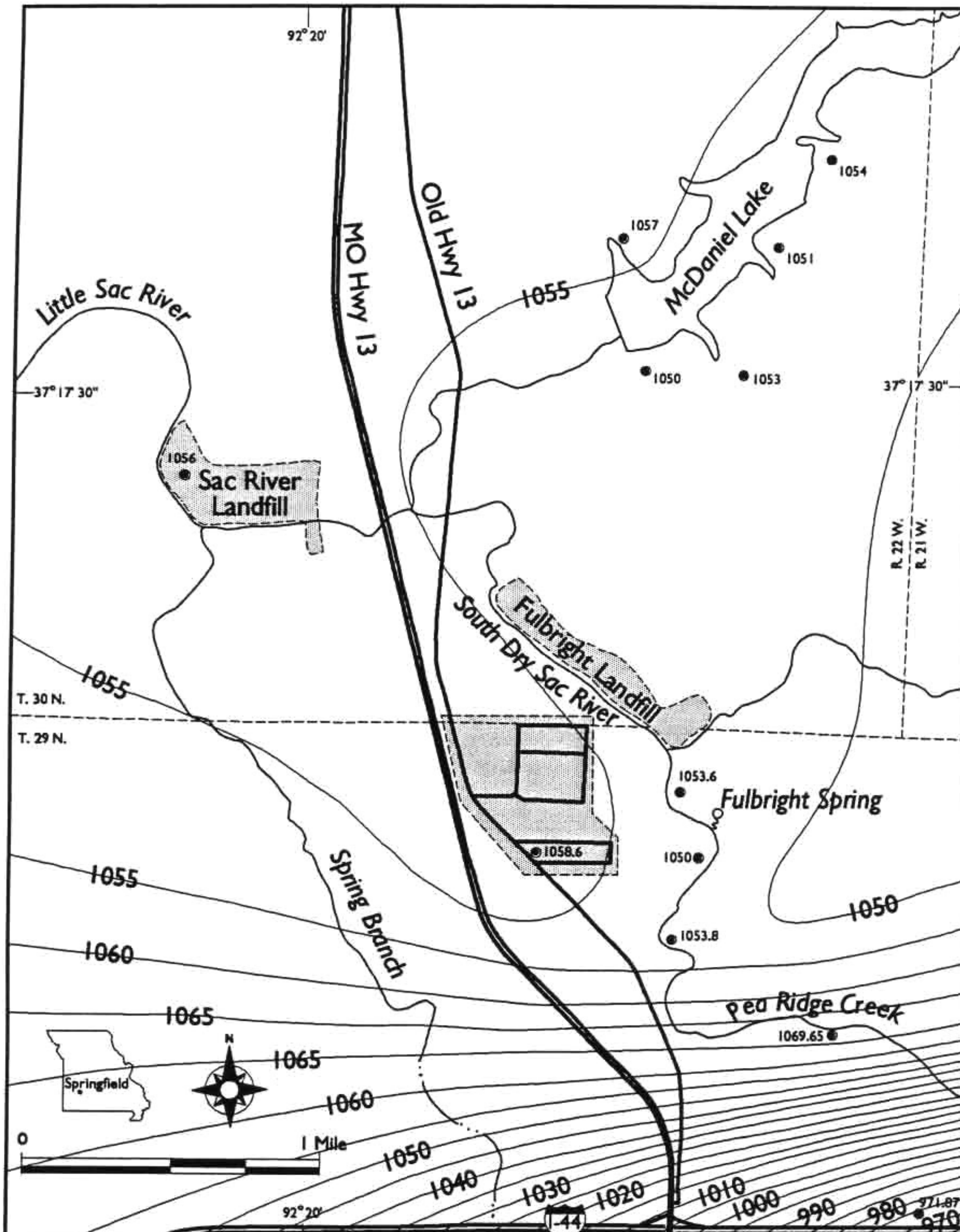

Figure 25. *Potentiometric map of the Ozark aquifer, June 15, 1993.*

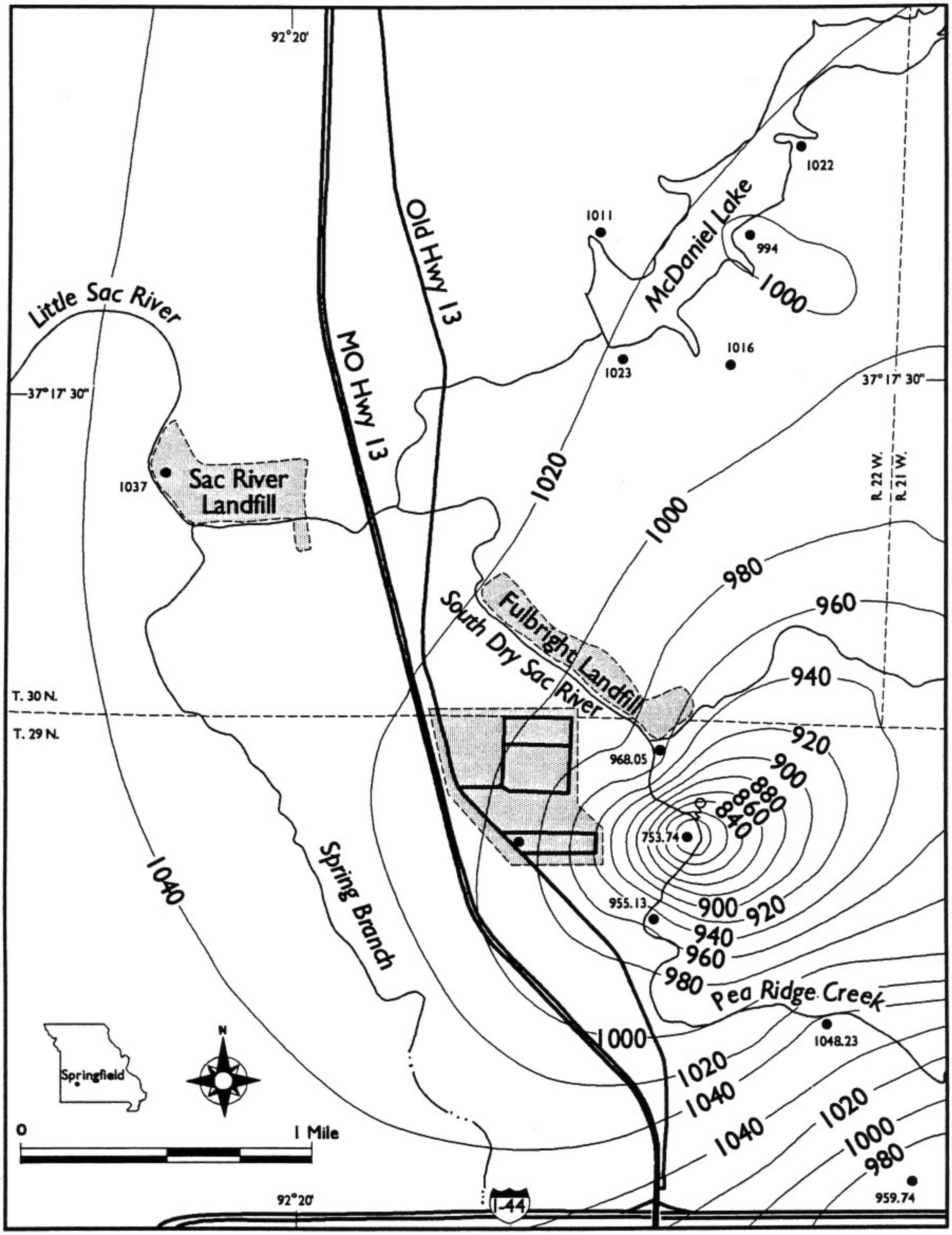

Figure 26. *Potentiometric map of the Ozark aquifer, October 1, 1993.*

TRANSMISSIVITY, STORATIVITY, AND HYDRAULIC CONDUCTIVITY OF THE OZARK AQUIFER IN THE FULBRIGHT AREA

The transmissivity of an aquifer is a quantitative measure of its capacity to transmit water. It is defined as the rate of flow of water through a unit width, vertical strip, of the aquifer extending its full saturated thickness under a unit hydraulic gradient. For example, an aquifer having a transmissivity of 10,000 gpd/ft would, in a days time, transmit 10,000 gallons of water through a vertical strip of the aquifer 1 ft wide under a hydraulic gradient of 1 ft/ft. The transmissivity of an aquifer is equal to its hydraulic conductivity times its saturated thickness.

The storativity of an aquifer, or its coefficient of storage, is defined as the amount of water the aquifer can take into or release from storage per unit surface area per unit change in head. For example, an aquifer having a storativity of 0.01 would release 0.01 ft^3 of water from a 1 ft by 1 ft area with a head decline of 1 ft.

The two months of pumping at Fulbright well #1 allowed an opportunity to calculate the hydraulic coefficients of the Ozark aquifer under relatively long-term pumping conditions. Generally, aquifer tests are conducted for much shorter pumping periods, and a 64 day aquifer test is a unique opportunity.

The pump in Fulbright well #1 was started on August 2, 1993, at about 1100 hrs. Based on Springfield City Utility production records for August, September, and October, average pumping rate was about 2,382 gpm. The pump stopped twice in September due to electrical problems. Each time, the pump was off for no more than a few hours before it was restarted.

Drawdown and recovery data collected at Fulbright wells #2 and #3, and North U Drive deep monitoring well, were analyzed using several standard aquifer analysis techniques. Time-drawdown and time-residual drawdown (recovery) data from Fulbright wells #2 and #3 were analyzed using the leaky artesian formula and the modified non-leaky artesian formula as presented in Walton (1962). Using these two techniques, four transmissivity values were calculated for each well. For well #2, calculated transmissivity ranged from 17,168 gpd/ft (2,295 ft^2/day) to 21,102 gpd/ft (2,821 ft^2/day), and averaged 19,140 gpd/ft (2,558 ft^2/day). Storativity values calculated using the different techniques varied much less, from 6.0×10^{-4} to 6.6×10^{-4}, and averaged 6.3×10^{-4}. Figures 27 and 28 show drawdown plots of well #2 analyzed using both techniques.

Transmissivity calculated at well #3 was slightly lower than at well #2. It ranged from 16,057 gpd/ft (2,146 ft^2/day) to 21,102 gpd/ft (2,821 ft^2/day), and averaged 18,270 gpd/ft (2,442 ft^2/day). Storativity was also somewhat lower than measured at well #2, ranging from 1.0×10^{-4} to 1.5×10^{-4}, and averaging 1.3×10^{-4}. Figures 29 and 30 show drawdown plots of well #3 analyzed using both techniques.

Data collected from the deep monitoring well at North U Drive were sufficient only for calculating transmissivity using the modified non-leaky artesian formula. Calculated transmissivity here was 12,678 gpd/ft (1,695 ft^2/day). However, this well does not completely penetrate the Ozark aquifer, and the transmissivity measured here likely reflects this. Storativity was calculated to be 5.2×10^{-4}.

Transmissivity and storativity were also calculated using distance-drawdown data and the modified non-leaky artesian formula. Using data from Fulbright wells #2 and #3, the five wells at McDaniel Lake, North U Drive deep monitoring well, and the Northwest Wastewater Treatment Plant well, transmissivity was calculated to be 19,960 gpd/ft (2,668 ft^2/day), and storativity was 1.6×10^{-4}.

Average hydraulic conductivity of an aquifer can be calculated by dividing the transmissivity by the saturated thickness. Using a transmissivity value of 19,000 gpd/ft (2,540 ft^2/day) and a saturated thickness of 1,200 ft, hydraulic conductivity is about 15.8 gpd/ft^2 (2.11 ft/day). This is somewhat less than the hydraulic conductivity values used by Imes and Emmett (in press) for the Ozark aquifer in the Springfield area, 6.91 ft/day to 11.23 ft/day.

Two months of pumping at Fulbright well #1 caused a significant, temporary decline in water level of the Ozark aquifer. Wells closest to Fulbright experienced the greatest drawdown, but wells more than 2 miles away still had drawdowns of about 40 feet. Water levels in the Springfield Plateau aquifer, however, did not show any appreciable change that could be attributed to production at well #1. Figure 31 shows water-surface elevations at Fulbright well #2 and at the USGS shallow monitoring well at Fulbright, along with precipitation at Springfield Regional Airport and well #1 daily production. Well #2 is about 1,120 ft from well #1, and the USGS well is about 1,200 ft from the pumped well. From this illustration, it can be seen that water-level fluctuations in the Springfield Plateau aquifer at Fulbright generally correspond to precipitation events, and that the USGS well does not appear to be affected by well #1. The Northview Formation is considered a leaky aquitard; it impedes the vertical movement of water but does not preclude it. However, even with the additional head potential across the Northview Formation following two months of pumping at well #1, the rate of leakage through the Northview Formation is probably too low to cause measurable water-level changes in the Springfield Plateau aquifer. It can also be seen from figure 31 that after two months of pumping, the potentiometric surface of the Ozark aquifer at well #2 was still above the top of the aquifer and that the aquifer was still under confined conditions at well #2.

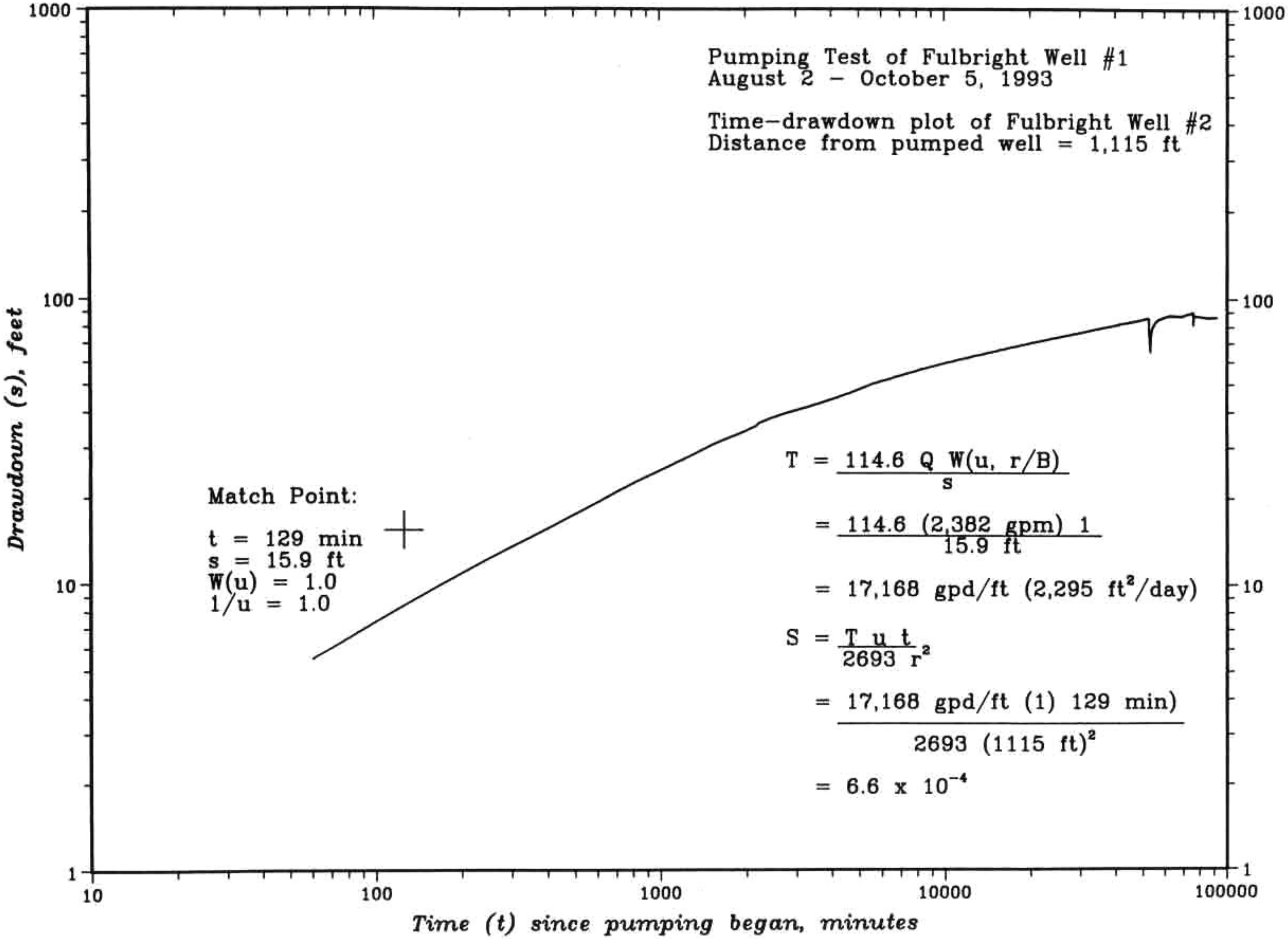

Figure 27. *Log-log plot of time versus drawdown, Fulbright well #2.*

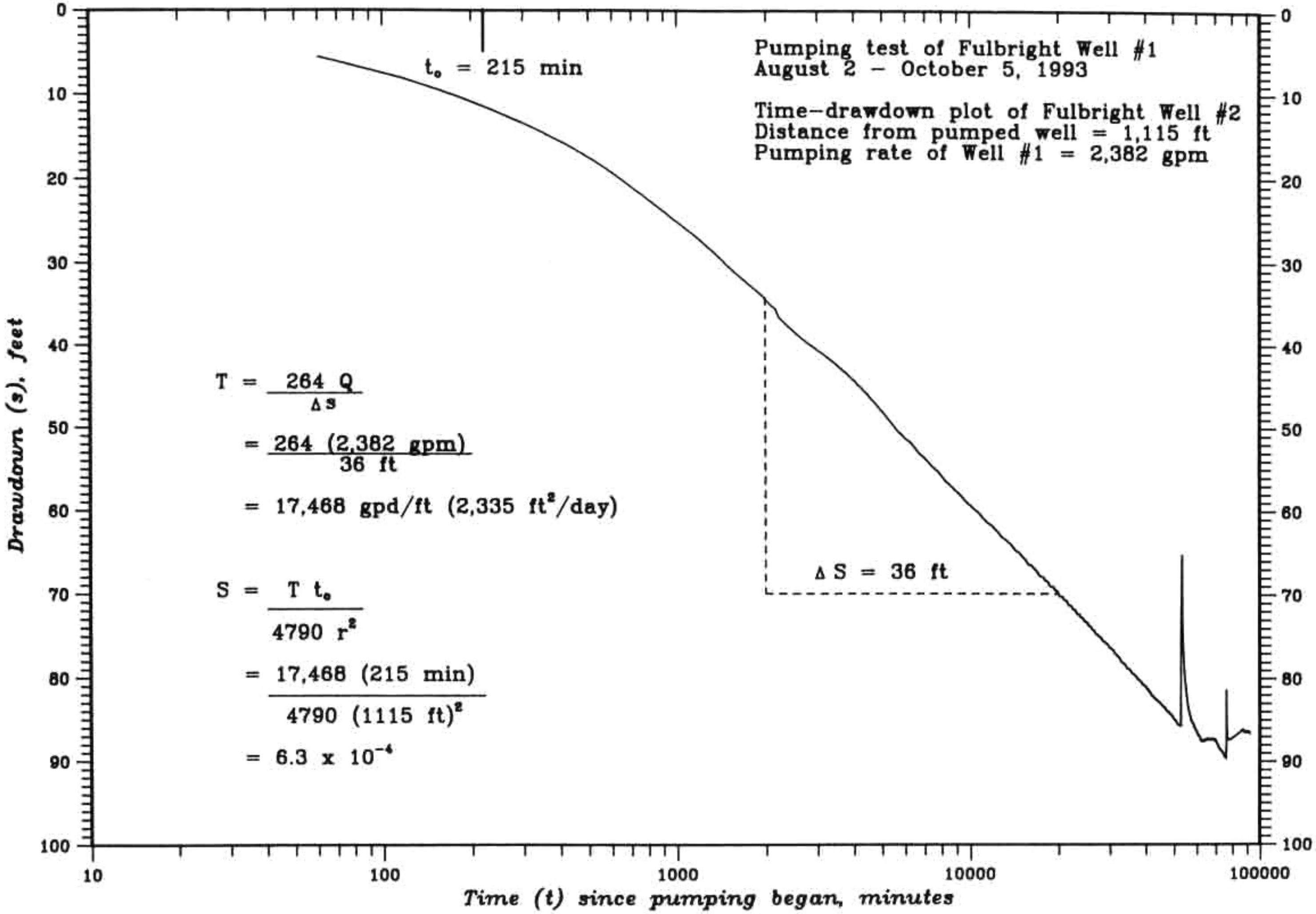

Figure 28. *Semi-log plot of time versus drawdown, Fulbright well #2.*

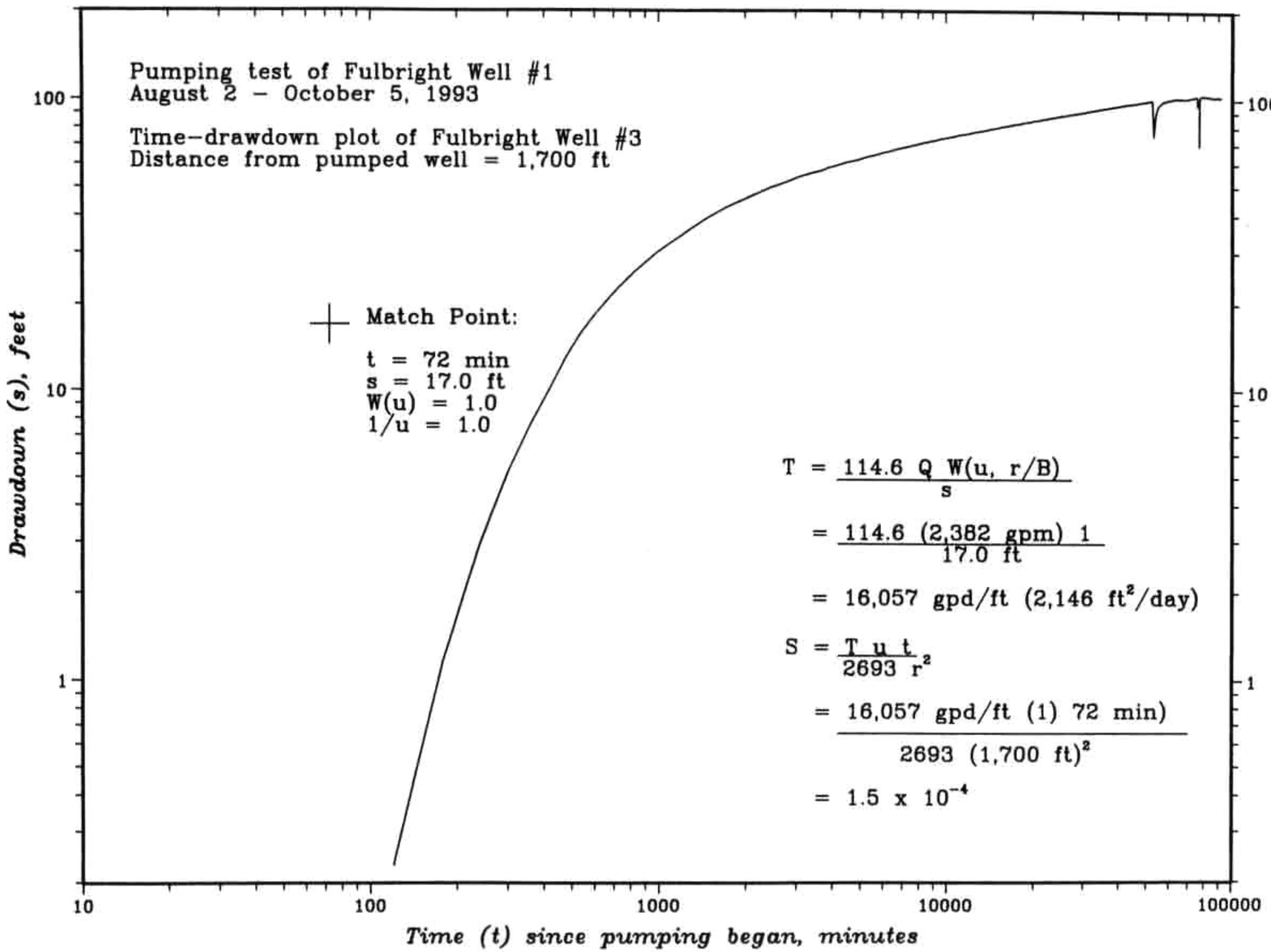

Figure 29. *Log-log plot of time versus drawdown, Fullbright well #3.*

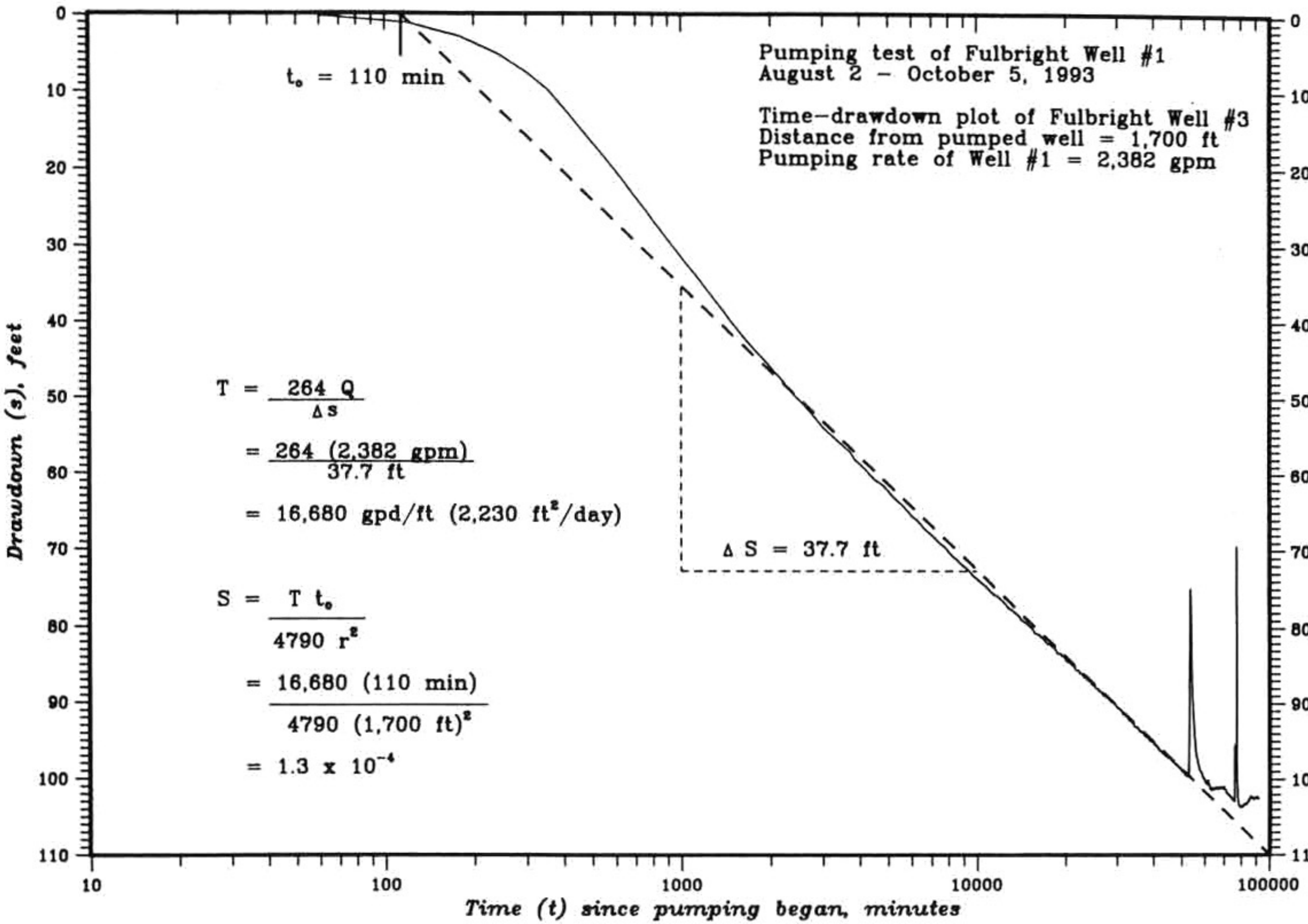

Figure 30. *Semi-log plot of time versus drawdown, Fulbright well #3.*

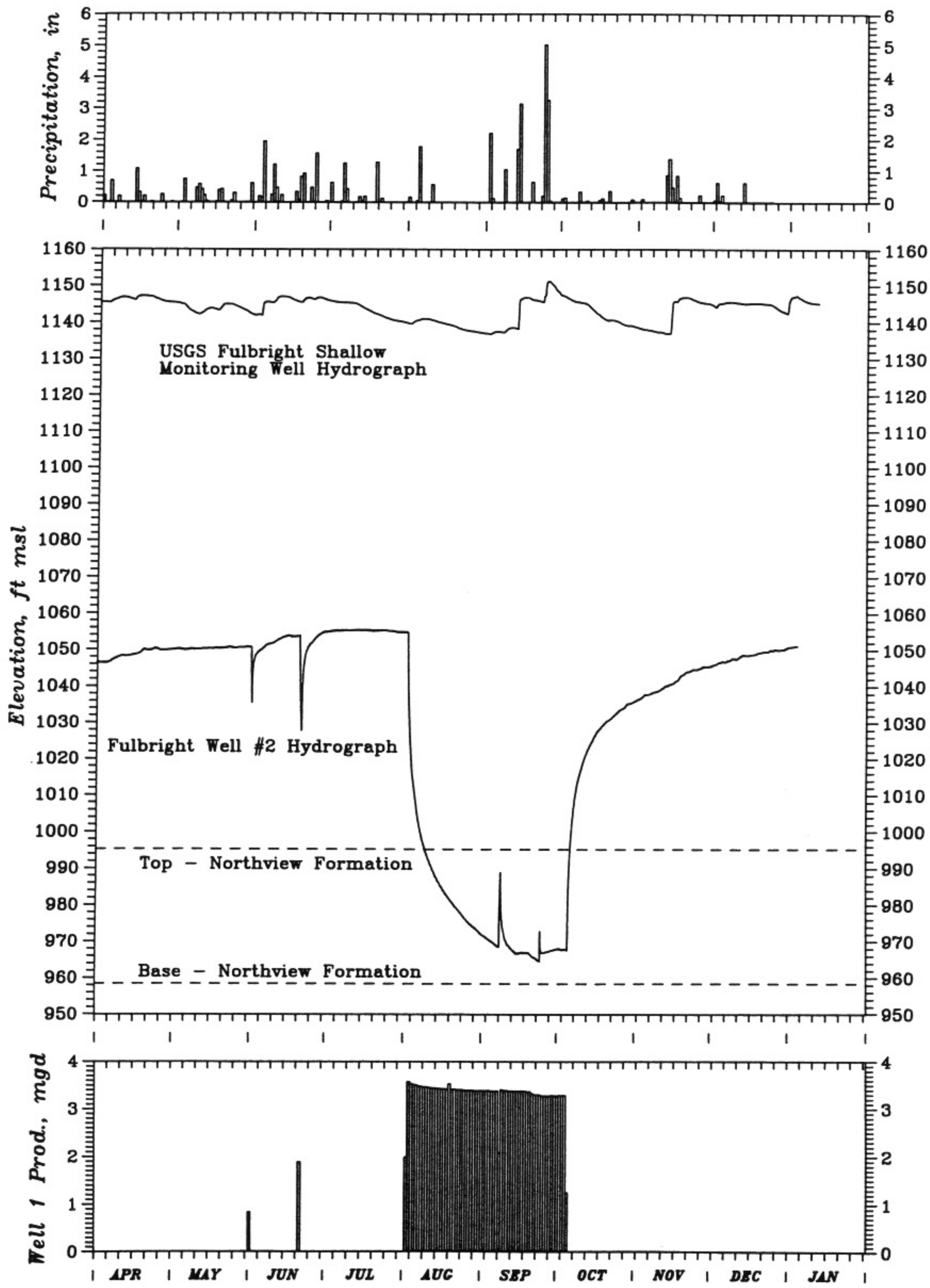

Figure 31. *Hourly water-level hydrographs of USGS Fulbright shallow monitoring well and Fulbright well #2, Springfield Regional Airport daily precipitation, and daily production at Fulbright well #1.*

Figure 32 shows similar data for the pair of monitoring wells at North U Drive. Normally, there is about 90 ft of head difference between the Springfield Plateau and Ozark aquifers here. After well #1 had been pumping for two months, it had increased to about 160 ft. Despite the greater downward hydraulic gradient, water levels in the Springfield aquifer did not show any effects from the pumping. As with the USGS Fulbright well, water-level elevation increases at North U Drive shallow monitoring well appear to be related to recharge from precipitation.

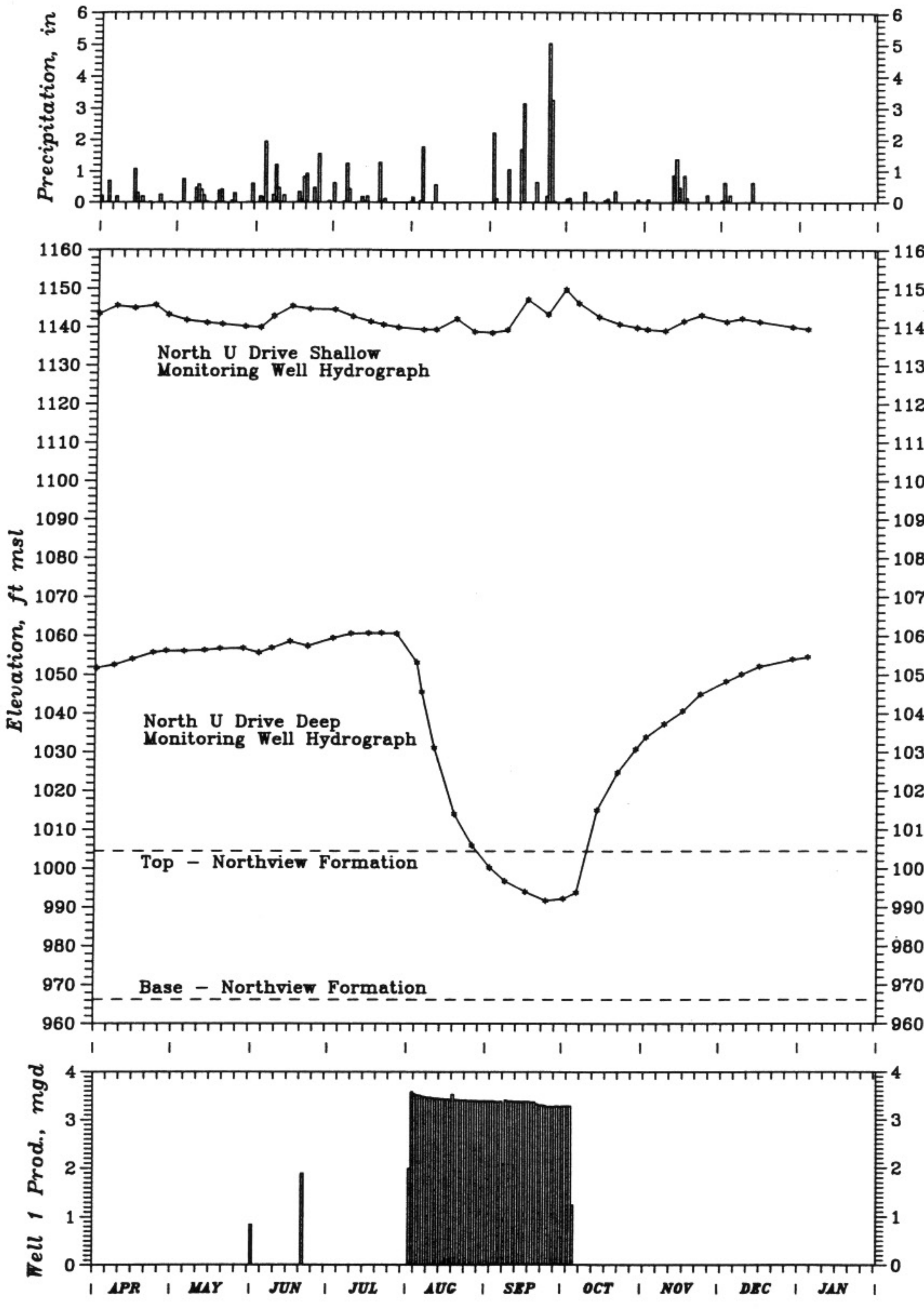

Figure 32. *Water-level hydrographs of North U Drive shallow and deep monitoring wells, Spring-field Regional Airport daily precipitation, and daily production at Fulbright well #1.*

WATER PRODUCTION AT THE FULBRIGHT WATER TREATMENT PLANT

As the potentiometric maps show, Fulbright well #1 has a major impact on hydraulic gradient and direction of groundwater movement in the Fulbright area. Historical water-supply data are presented for the Fulbright Water Treatment Plant to show how production from the well has changed over time, and to help determine its overall impact on potential contaminant transport in the Fulbright area.

The City of Springfield relies on numerous raw water sources to meet the water demands of Missouri's third largest city. Unlike many cities of similar size, it is not located along a major river that can be used to meet its entire water-supply needs. Instead, Springfield depends on numerous sources including wells, reservoirs, the James River, and Fulbright Spring.

Fulbright Spring was Springfield's original public water supply and is still used for that purpose. When the privately owned Springfield City Water Company began operating in 1883 it had about 1,000 customers and supplied them from Fulbright Spring (Springfield City Utilities brochure, undated). In 1914 and 1915, three deep wells were drilled along Pea Ridge Creek upstream, adjacent to, and downstream of Fulbright Spring. Although all three wells fully penetrate the Ozark aquifer, each had different yield characteristics. Well #1 had the highest yield, and became an important water-supply source. Well #2 had a lower yield, and was used much less frequently than #1. The yield of well #3 was apparently so low that the water company never equipped it with a permanent pump.

During periods of normal rainfall, Fulbright Spring and well #1 were adequate to meet water demands, but were not adequate to supply the growing city during drought periods. To help alleviate this problem, the water company constructed McDaniel Lake on the Little Sac River north of Fulbright Spring. Water from the reservoir, completed in 1929, is transported to Fulbright Water Treatment Plant by pipeline. Fellows Lake, which is upstream of McDaniel Lake on the Little Sac River, was added to the system in 1955.

In 1957, the City of Springfield purchased the privately owned water company, and placed its management under Springfield City Utilities.

Fulbright Water Treatment Plant, which was built between 1937 and 1941, supplied essentially all of Springfield's municipal water until the Blackman Water Treatment Plant was finished in 1981. Fulbright has a nominal capacity of about 24 mgd, and can receive water from McDaniel Lake, Fellows Lake (by surface flow into McDaniel Lake), Fulbright Spring, and Fulbright well #1. Water can also be pumped from the James River into Fellows Lake to further increase capacity.

Water-supply data for Fulbright Water Treatment Plant were analyzed to determine the effects that Fulbright well #1 production may have had in the area, and to illustrate the importance of this water-supply source to Springfield. Monthly water-supply information for the Fulbright Water Treatment plant was obtained from Springfield City Utilities for March 1971 through December 1993. Monthly data by source were missing for the period April 1978 through December 1980. Yearly totals were obtained by examining the daily operation logs for that period, but source-specific data were not available.

Figure 33 shows monthly water production for Fulbright Spring, McDaniel Lake, and Fulbright well #1; figure 34 shows the percentage of the monthly total that each supplied. Generally, when spring flow is ample, Fulbright Spring is used as the primary water source. In terms of cost, it is the cheapest source of raw water at Fulbright. During dry weather when spring flow becomes inadequate, or when there are water-quality problems with the spring due to suspended sediment, McDaniel Lake is typically used. However, during late summer, water from McDaniel Lake may develop taste or odor problems that are difficult to treat. Additionally, this is the time when flow of Fulbright Spring is typically lowest because of dry weather. It is this time when Fulbright well #1 is typically most heavily used. If pumped continuously, Fulbright well #1 can produce about 103 million gallons per month. Depending on overall demand, well #1 has supplied as much as about 60 percent of the raw water during a month, but more typically supplies about 25 percent.

Figure 35 shows the yearly production by source at Fulbright, and figure 36 shows the percentage of the total supplied by each source. Actual values are shown in table 1.

Between 1971 and 1993 (including April 1978 through December 1980), about 110 billion gallons of water were treated and distributed through Fulbright Water Treatment Plant. About 50.2 percent of the water, more than 45.3 billion gallons, was from Fulbright Spring. McDaniel Lake supplied about 41.8 percent of the raw water, which is more than 37.7 billion gallons. Fulbright well #1 produced about 7.9 percent of the total, which equates to about 7.16 billion gallons. Between 1971 and 1994, Fulbright Spring supplied between 31.9 percent and 64.4 percent. McDaniel Lake

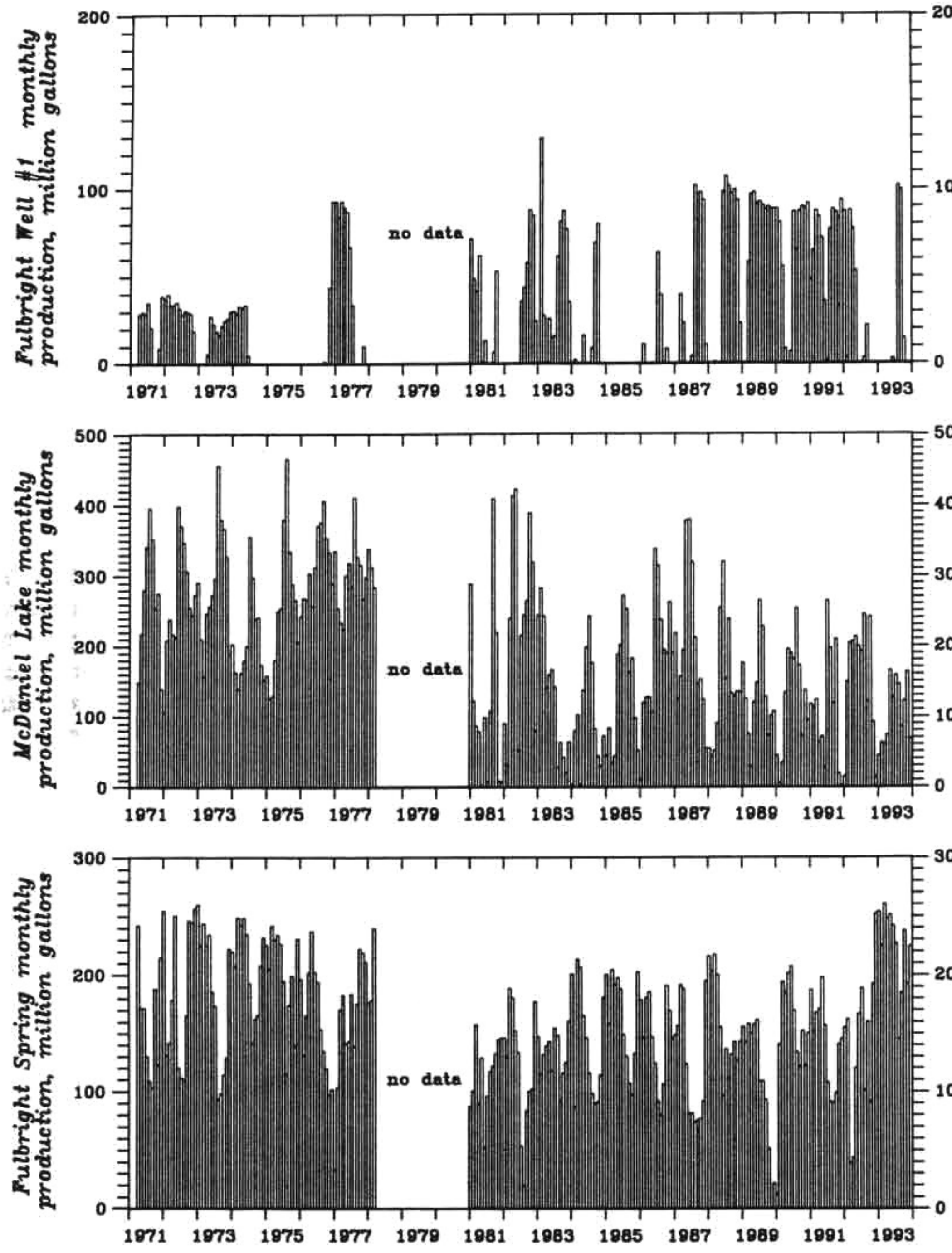

Figure 33. *Monthly production, 1971 through 1993, Fulbright Spring, McDaniel Lake, and Fulbright well #1.*

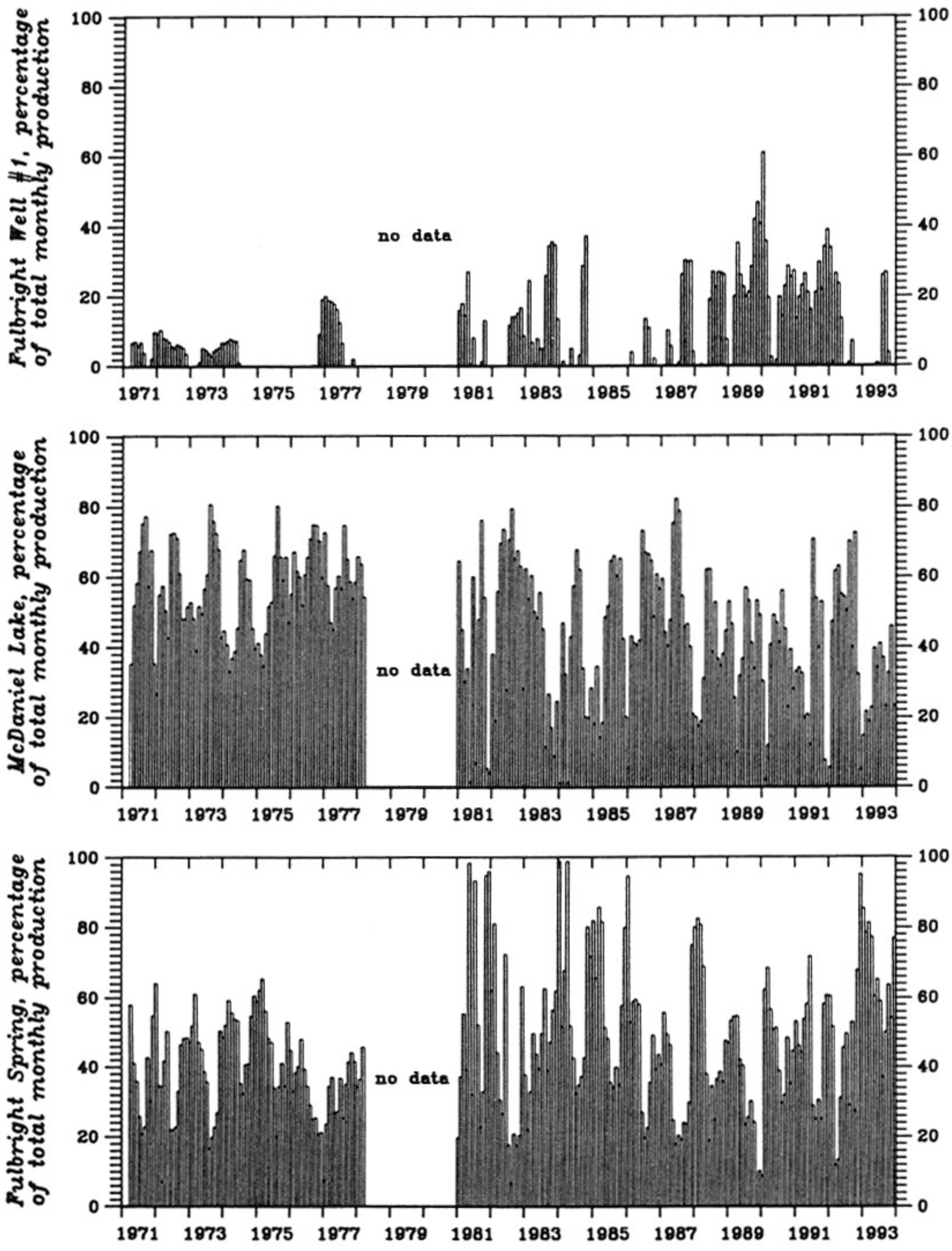

Figure 34. *Percentage of total monthly production, 1971 through 1993, Fulbright Spring, McDaniel Lake, and Fulbright well #1.*

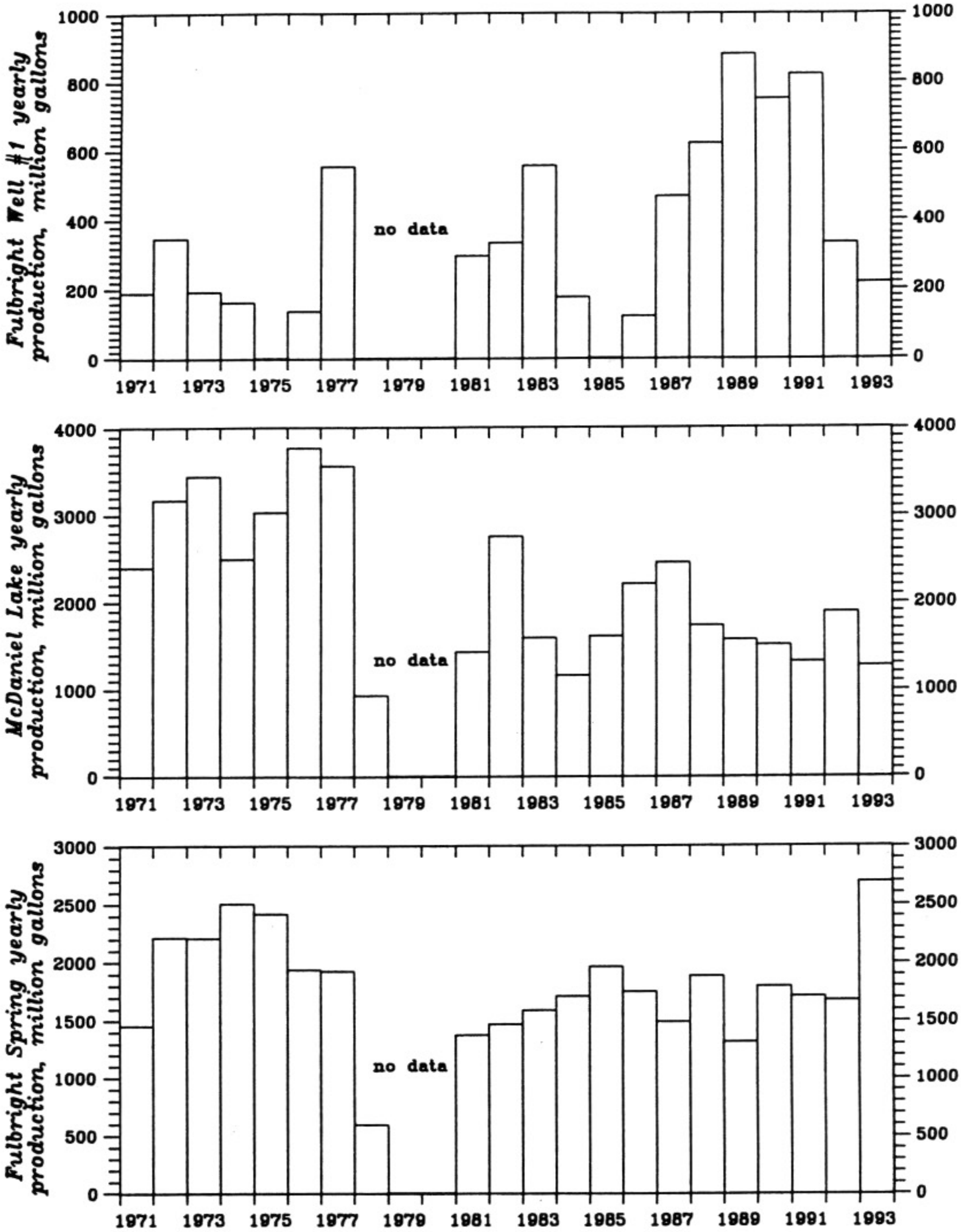

Figure 35. *Yearly production by source, 1971 through 1993, Fulbright Spring, McDaniel Lake, and Fulbright well #1.*

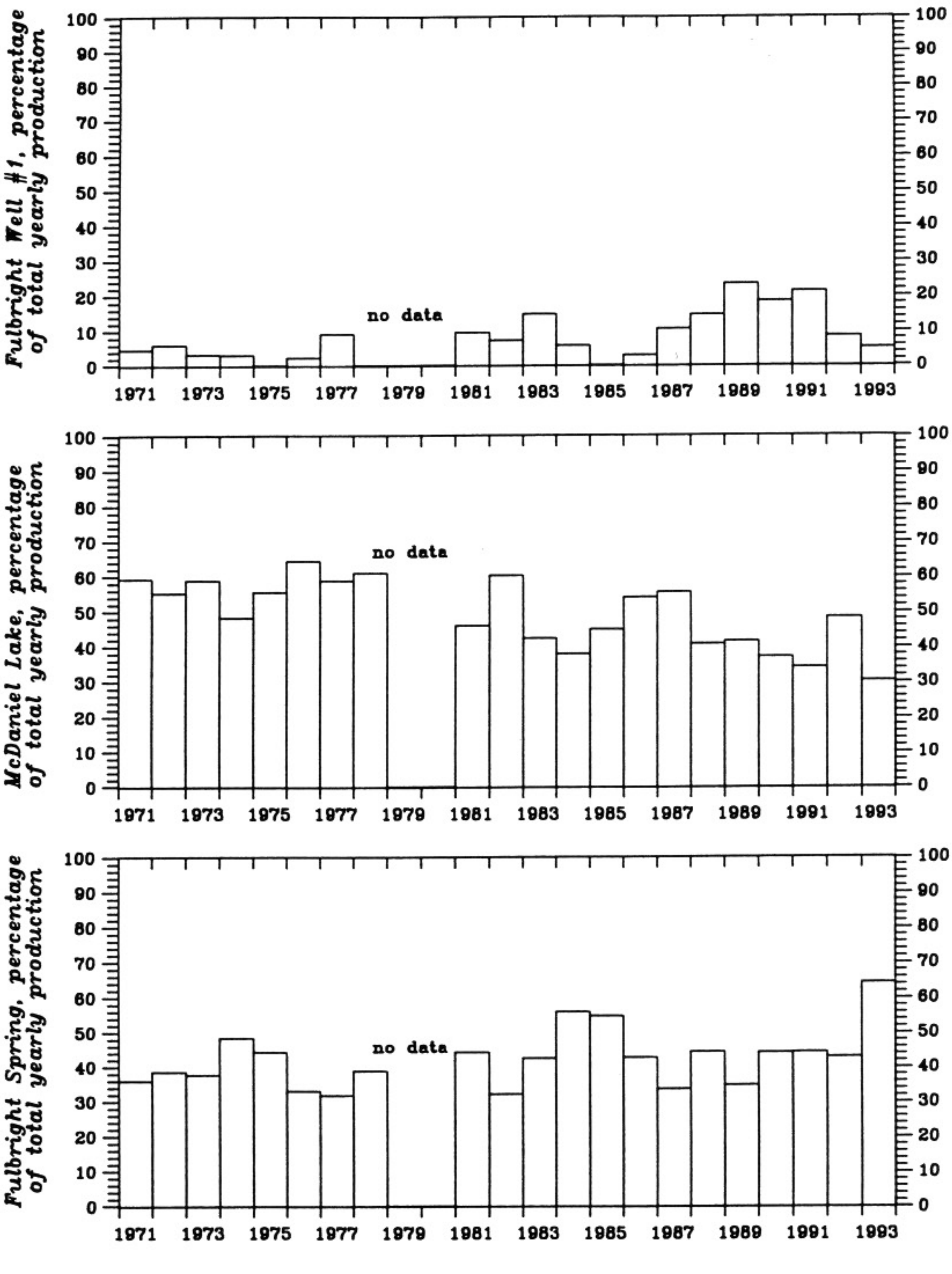

Figure 36. *Percent of total yearly production by source, 1971 through 1993, Fulbright Spring, McDaniel Lake, and Fulbright well #1.*

supplied between 30.4 percent and 64.5 percent. Yearly production from well #1 varied from zero to 23.4 percent of the total.

Although the volume of water supplied by well #1 appears relatively small, its importance as a supply to the City of Springfield should not be underestimated. Since it is the most expensive raw water source at Fulbright, economics dictate that it be used only when needed, and for no longer than necessary. In periods of dry weather, peak demand, or when there are water quality problems or mechanical problems with other raw water sources, well #1 becomes very important. In 1993, it was pumped just over two months, and produced 218 million gallons, which was 5.2 percent of the total water production at Fulbright. However, in 1989, 1990, and 1991 it supplied 18.5 percent to 23.4 percent of the raw water at Fulbright.

YEAR	McDANIEL LAKE MGAL	% TOTAL	FULBRIGHT SPRING MGAL	% TOTAL	FULBRIGHT WELL #1 MGAL	% TOTAL	YEARLY TOTAL MGAL
1971	2400.1*	59.3*	1455.5*	36.0*	189.6*	4.7*	4045.2*
1972	3171.8	55.3	2213.9	38.6	346.8	6.0	5732.5
1973	3443.5	58.9	2207.6	37.8	193.4	3.3	5844.5
1974	2497.1	48.3	2507.3	48.5	162.6	3.1	5167.0
1975	3029.7	55.6	2419.4	44.4	0.0	0.0	5449.1
1976	3771.3	64.5	1939.1	33.2	137.0	2.3	5847.4
1977	3560.9	58.9	1927.7	31.9	555.2	9.2	6043.8
1978	933.7*	61.1*	594.8*	38.9*	0.0*	0.0*	(6459.4)
1979	******	****	******	****	******	****	(6357.0)
1980	******	****	******	****	******	****	(6893.1)
1981	1428.2	46.1	1376.1	44.4	296.1	9.6	3100.5
1982	2754.3	60.4	1471.3	32.3	334.2	7.3	4559.7
1983	1590.3	42.5	1592.9	42.6	556.7	14.9	3740.0
1984	1163.9	38.1	1713.2	56.1	176.7	5.8	3053.8
1985	1611.2	45.1	1964.4	54.9	0.0	0.0	3575.5
1986	2213.3	54.1	1752.1	42.9	122.6	3.0	4087.9
1987	2455.3	55.6	1490.2	33.8	467.9	10.6	4413.4
1988	1733.9	40.9	1884.8	44.5	620.5	14.6	4239.3
1989	1569.2	41.7	1313.7	34.9	882.0	23.4	3765.0
1990	1510.3	37.2	1796.1	44.3	750.0	18.5	4056.3
1991	1320.5	34.3	1712.6	44.4	822.2	21.3	3855.2
1992	1889.2	48.4	1677.7	43.0	333.2	8.5	3900.1
1993	1271.5	30.4	2695.7	64.4	218.4	5.2	4185.6
TOTALS	37706.2	41.8	45319.1	50.2	7165.1	7.9	90190.4

Note: Monthly data missing from January 1971 through March 1971, and from April 1978 through December 1980.

* Indicates data for yearly productions, percentages, and totals are incomplete.

*** Indicates missing data.

() Yearly values in parenthesis are from Fulbright daily operation logs. Data by source are not available. Long term totals do not include these values.

Table 1. *Yearly production and yearly percentage of total production, Fulbright Spring, McDaniel Lake, and Fulbright well #1.*

POTENTIAL EFFECTS OF FULBRIGHT LANDFILL ON FULBRIGHT WELL #1 WATER QUALITY

A primary objective of this study is to determine if Fulbright Landfill, Sac River Landfill, or the North U Drive site present a significant risk to Fulbright well #1. Well #1 is only about 1,800 ft from the southeast end of Fulbright Landfill, and since it is the closest of the three sites, it is reasonable to assume that it presents the greatest potential risk.

Analyses of several hydrologic scenarios are presented in the following paragraphs. Each briefly analyzes a possible contaminant-transport pathway. Darcy's law is used to estimate groundwater velocities and flow rates. This is done with the understanding that actual water movement through fractured rock, particularly rock containing solution-enlarged openings, may vary substantially from that predicted using Darcy's law. Where possible, measured values are used in the analyses. When assumed values are used they are identified as such.

The SCS engineers (1988) performed a remedial investigation study of the Fulbright and Sac River landfills. Several monitoring wells were installed at both landfills and used for water-quality sampling, as well as water-level measurements. Slug tests were performed on several of these wells by SCS to determine hydraulic conductivity of the alluvium and shallow bedrock. The bedrock wells drilled at Fulbright Landfill were relatively shallow, generally about 40 ft deep, and did not fully penetrate the Springfield Plateau aquifer. The endangerment assessment presented by SCS in 1988 for the Fulbright Landfill was based greatly on the assumption that the water level in the Ozark aquifer is at or above the water level in the Springfield Plateau aquifer. This was based on a water-level measurement taken at Northwest Wastewater Treatment Plant well when it was being constructed. According to this report, the only "tightly-cased" well on either landfill was at the Northwest Wastewater Treatment Plant (SCS, 1988, p. 3-11). Fulbright well #2, while not within Fulbright Landfill, per se, is only a few feet from it, and is cased and pressure grouted through the Northview Formation. Based on data from the Northwest Wastewater Treatment Plant Well, SCS assumed an upward flow potential across the Northview Formation at both landfills, and concluded that the Ozark aquifer potentiometric surface had a northwesterly gradient.

Based on hourly water-level data collected between April 1993 and January 1994, when Fulbright well #1 is not pumping, the water level in Fulbright well #2 is at an elevation of about 1,050 ft. Monthly water-level data were collected by SCS (1988) from August 1986 through March 1987 from alluvial and shallow bedrock wells at the Fulbright Landfill. In the southeast end of the landfill, only a few hundred feet from Fulbright well #2, water levels in the shallow aquifer were at an elevation of nearly 1,095 ft. Instead of an upward flow potential across the Northview Formation, these data show a downward head potential across the Northview Formation of about 45 ft. A natural gamma log of Fulbright well #2 shows top and bottom of the Northview Formation at approximate elevations of 995 ft and 959 ft, respectively, and the thickness of the formation is about 36 ft.

In 1988, SCS measured hydraulic conductivity at two shallow bedrock wells in the Fulbright Landfill. The values varied from 1.4×10^{-5} ft/sec to 1.4×10^{-7} ft/sec. Imes and Emmett (in press) estimate average hydraulic conductivity of the Springfield Plateau aquifer to be 2.5×10^{-4}. As with most carbonate rock aquifers, hydraulic conductivity varies with location and vertical position in the Springfield Plateau aquifer. In the following paragraphs, calculations are based on an assumed hydraulic conductivity of 1×10^{-5} for the Springfield Plateau aquifer. Actual hydraulic conductivity could vary from this an order of one magnitude or more.

The hydraulic conductivity of the Northview Formation has been estimated by several workers, but actual measurements, at least in the Fulbright area, have apparently never been made. Imes and Emmett (in press) estimate the Ozark confining unit to have a hydraulic conductivity of 3×10^{-8} ft/sec in the Springfield area. The SCS (1988) uses a value of 1×10^{-9}, which corresponds to a value shown in Emmett and others, 1978. Calculations in this section involving vertical hydraulic conductivity of the Northview Formation use both of these values for comparison. An effective porosity of 20 percent is assumed for the Northview Formation.

Hydraulic conductivity of the Ozark aquifer in the Fulbright area was calculated from the two-month pumping test of Fulbright well #1. Based on a transmissivity of 19,000 gpd/ft (2,540 ft^2/day) and a saturated thickness of 1,200 ft, is 2.11 ft/day. It must be understood that hydraulic conductivity of the Ozark aquifer not only varies spatially, but it also varies vertically. Hydraulic conductivity of certain zones is likely to be much greater than 2.11 ft/day, while other zones may have a much lower hydraulic conductivity.

The first contaminant transport scenario analyzed is the potential for downward migration of contaminants from the Fulbright Landfill through the Northview Formation and into the Ozark aquifer. Under non-pumping conditions, there is about 45 feet of head difference between the Springfield Plateau aquifer and the Ozark aquifer at the southeast end of Fulbright Landfill. Based on a vertical hydraulic conductivity of 3×10^{-8} ft/sec, a vertical hydraulic gradient of 45 ft across 36 feet of Northview

Formation, and an assumed porosity of 20 percent for the Northview Formation, velocity through the Northview is calculated to be 1.9×10^{-7} ft/sec. This equates to 1.6×10^{-2} ft/day, or about 6.0 ft/year. Based on these calculations, about six years would be necessary for water to move from the base of the Springfield Plateau aquifer, through the Northview Formation, into the Ozark Plateau aquifer. Again using these figures, the volume of leakage through the Northview Formation beneath the Fulbright Landfill, which measures about 4,300 ft by 500 ft, is calculated to be 8.1×10^{-2} ft^3/sec, or about 52,100 gallons per day.

When Fulbright well #1 is pumping, the head difference across the Northview Formation in the southeastern end of the Fulbright Landfill increases to about 125 ft. Using the above values, the increased head pressure increases velocity through the Northview Formation to 5.3×10^{-7} ft/sec, which is equal to 4.5×10^{-2} ft/day or about 16.5 ft/yr. Based on this, about 2.2 years would be needed for water to flow through the Northview Formation. Calculated leakage through the Northview Formation also increases due to the head increase to 0.22 ft/sec, or 148,000 gallons per day.

The SCS (1988) used a vertical hydraulic conductivity of 1×10^{-9} ft/sec for the Northview Formation. Based on this value, the velocity of water moving through the Northview Formation when Fulbright well #1 is not pumping is calculated to be 6×10^{-9} ft/sec. This equals 5.4×10^{-4} ft/day, or about about 0.2 ft/year. Using this value, it would take water about 180 years to move through the Northview Formation. When Fulbright well #1 is pumping, the hydraulic gradient across the Northview Formation increases to about 125 ft, and the velocity increases to 1.7×10^{-8} ft/sec. This is equal to 1.5×10^{-3} ft/day, or about 0.55 ft/year, indicating a travel time of about 66 years. Using this hydraulic conductivity, leakage through the Northview Formation beneath the Fulbright Landfill under non-pumping conditions is calculated to be 2.7×10^{-3} ft^3/sec, or about 1,740 gallons per day. When well #1 has been pumped for an extended period, this increases to 7.5×10^{-3} ft^3/sec, or about 4,825 gallons per day.

If contaminants pass through the Northview Formation and enter the Ozark aquifer, their movement is to a great extent controlled by pumpage at Fulbright well #1. Under non-pumping conditions, water level at well #1 is at an elevation of about 1050 ft. Water-level elevation in Fulbright well #2 is about 1053 ft, which indicates that there is a relatively low gradient between Fulbright well #2 and Fulbright well #1 during non-pumping periods. After Fulbright well #1 had been pumping for two months, water level in Fulbright well #2 was at an elevation of about 970 ft, while water level in well #1 was at an elevation of about 755 ft. Based on the potentiometric map, water level beneath the southeastern end of the Fulbright Landfill was at an elevation of 950 ft. Distance between Fulbright well #1 and the landfill is about 1,800 ft. Using a hydraulic conductivity of 2.11 ft/day, a head loss of 195 ft over 1,800 ft, and an effective porosity of 10 percent, velocity between the landfill and well #1 during periods of pumping is calculated to be about 2.52 ft/day, or 919 ft/yr.

Based on this, less than 2 years would be required for water to travel from the southeastern end of the Fulbright Landfill to Fulbright well #1, if well #1 was pumped nearly continuously.

Fulbright well #1 contains about 148 ft of casing that bottoms at about the base of the Northview Formation. However, the casing is not thought to be pressure grouted. It is not known if any grouting was attempted when the casing was installed. A review of water-quality data for well #1 indicates that the casing is not sealed. Periodically, the water contains bacteria, and calcium/magnesium ratios calculated from water analyses indicate that water from the Springfield Plateau aquifer is entering the well. Calcium/magnesium ratios for the Ozark aquifer, expressed as milli-equivalent/liter, are typically low, about 1.5 to 2, reflecting water that has been in contact with dolomitic rock. Water produced from the Springfield Plateau aquifer, which is primarily limestone, generally has a much higher calcium/magnesium ratio, about 10 to 20. Calcium/magnesium ratios calculated from water-quality data from well #1 vary widely, from about 1.5 to more than 30. The low values may be due to samples being collected after well #1 has been in operation for a relatively long period, while the higher values are from samples collected after the pump has been operating only a short time. The most likely way that water from the Springfield Plateau aquifer is entering the well is from around the outside on the unsealed casing.

Since it appears that Fulbright well #1 is open to the Springfield Plateau aquifer, the possibility of lateral migration of contaminants through the Springfield Plateau aquifer to Fulbright well #1 should be considered. Based on data collected by SCS (1988), water level in the Springfield Plateau aquifer at the southeast end of the Fulbright Landfill is at an elevation of about 1095 ft. During non-pumping periods, water-level elevation in well #1 is about 1050 ft, which indicates a gradient in the Springfield Plateau aquifer toward Fulbright well #1 from the landfill. Using a lateral hydraulic conductivity of 1×10^{-5} ft/sec for the Springfield Plateau aquifer, a head-loss of 45 feet over 1,800 ft, and an assumed effective porosity of 15 percent, velocity of groundwater between the Fulbright Landfill and Fulbright well #1 is about 1.7×10^{-6} ft/sec, or 52.4 ft/year. Under these conditions, in 25 years groundwater could have moved about 1,300 ft.

When well #1 is pumping, its water level is several hundred feet below the base of the Springfield Plateau aquifer. Thus, if the casing in well #1 is not sealed, water in the Springfield Plateau aquifer can drain into well #1. This likely causes substantial drawdown in the shallow aquifer adjacent to the well. Under these conditions, the gradient between the Fulbright Landfill and well #1 is increased to as much as 100 ft over the 1,800-ft distance. Based on this gradient, velocity between the landfill and well is 3.7×10^{-6} ft/sec. Under these conditions, water could move as much as 0.32 ft/day, or 117 ft/year.

Although calculations indicate that it is possible for contaminants from the Fulbright landfill to have reached well #1, water-quality data for well #1 do not indicate that this has occurred. Water-quality data supplied by Springfield City Utilities show low concentrations of metals in well #1. Metals analyses from 16 samples collected between May 1984 and October 1986 showed lead concentrations to be consistently below the detection limit of 10 ug/l. Similar samples collected between October 1987 and October 1989 showed lead concentrations below detection limits (10 ug/l) for seven samples, and values between 5 ug/l and 16 ug/l for seven other samples. Analyses of metals for 12 samples collected between May 1991 and September 1993 showed lead to vary from below detection limits to a maximum of 12 ug/l.

The only water-quality data which suggests that Fulbright well #1 may have received contaminants from the Fulbright Landfill is a 1982 analysis performed by Wilson Laboratories for City Utilities. The analysis showed a total cyanide concentration of 0.08 mg/l; the detection limit was 0.01 mg/l. Also, trichloroethylene was detected at a concentration of 9 ug/l. A sample taken the previous year and analyzed by Wilson Laboratories did not test for total cyanide, but neither trichloroethylene nor any of the 17 other volatile organic compounds tested for were detected in the sample. Another analysis for cyanide and trichloroethylene by the same laboratory in 1985 also proved negative.

Another contaminant-transport pathway, and one which may be the most logical, is water movement from the Fulbright Landfill through the alluvium and shallow bedrock into the South Dry Sac River. Potentiometric maps of the alluvium and shallow bedrock at the Fulbright Landfill prepared by SCS (1988) show groundwater movement from northeast to southwest, from the valley wall toward the the South Dry Sac River. The potentiometric map contours show a gradient of about 0.0125 ft/ft. Lateral hydraulic conductivity of the alluvium measured by SCS (1988) was about 9×10^{-5} ft/sec. Porosity of the alluvium is assumed to be 15 percent. Based on these values, velocity of groundwater in the alluvium is about 6.6×10^{-6} ft/sec. This is equal to a velocity of 0.58 ft/day, or 210 ft/yr. The Fulbright Landfill is only about 500 ft wide, and based on SCS (1988) potentiometric maps, direction of groundwater movement parallels the short axis of the landfill.

CONCLUSIONS

Data gathered during this study, combined with extensive existing information from various other sources, helps to answer several important hydrologic questions. Potentiometric maps of the Ozark aquifer show a relatively flat groundwater gradient in the area between Fulbright well #1 and the Northwest Wastewater Treatment Plant when well #1 is not pumping. The gradient appears to be to the southeast toward well #1, but minor changes in water level could reverse the gradient. When well #1 is operating, it creates an extensive pumping cone and becomes the major controlling factor for direction of groundwater movement in the Ozark aquifer in much of the study area.

Hydrologic data from the Fulbright Landfill area demonstrates that even when well #1 is not pumping, there is a significant downward-flow potential between the Springfield Plateau aquifer and Ozark aquifer at the landfill. When well #1 is in operation, the head difference between the two aquifers increases from about 45 ft to about 130 ft. The Fulbright Landfill has been closed for approximately 25 years. Hydrologic analyses indicate that under certain conditions it appears possible for groundwater in the Fulbright Landfill to have moved to Fulbright well #1, either through the Springfield Plateau aquifer or through the Ozark aquifer. Contaminant movement from the landfill to the well through the Ozark aquifer assumes that the higher of the two reported values of hydraulic conductivity for the Ozark confining unit, 3×10^{-8} ft/sec, is correct. Based on the lower hydraulic conductivity, 1×10^{-9} ft/sec, there has not been sufficient time for water to have moved downward through the Northview Formation into the Ozark aquifer; water-quality data from Fulbright well #1 generally supports this. However, based on the SCS (1988) study, metals concentrations in the Fulbright Landfill are generally less than 1 mg/l. Dilution could lower the concentration of contaminants to below detection limits. Fulbright well #2, which is very close to the landfill, could be used as a sampling point to determine if contaminants from the landfill have migrated into the Ozark aquifer. There are no Springfield Plateau aquifer wells between the landfill and Fulbright well #1. Placement of a monitoring well between these two points would allow water-level data as well as water-quality data to be collected. The water-level data would be necessary to determine if water draining from the Springfield Plateau aquifer into the Ozark aquifer from around the casing of well #1 is affecting direction of groundwater movement in the shallow aquifer.

Groundwater velocity calculations based on water levels and hydraulic conductivity data collected by SCS (1988) indicates that there may have been considerable contaminant transport through the alluvium into the South Dry Sac River. Calculations indicate that it may take less than 3 years for water to move southwest across the short dimension of the landfill to the stream. In the 25 years since the landfill closed, much of the leachate in the landfill could have been flushed through the alluvium and into the South Dry Sac River. Data collected from the four Springfield Plateau aquifer monitoring wells show that in most places in the study area the shallow aquifer responds very quickly to precipitation. Generally, rainfall events of an inch or more caused a significant change in water level. The shallow USGS well at McDaniel Lake, however, showed very little fluctuation during the study, and responded only slightly to even major rainfalls. Not enough Springfield Plateau aquifer wells were monitored to be able to construct an accurate potentiometric map of that aquifer. However, water-level elevations were generally highest in the upland areas and lowest in the valleys. Direction of groundwater movement in the shallow aquifer appears to be toward the Sac River valley and its major tributaries.

A concern that helped prompt this study was the apparent similarity between some of the contaminants found at the North U Drive site, and the leachate at Fulbright Landfill. Lead concentrations exceeding 50 ug/l were found in several wells in the North U Drive area during a remedial investigation performed by Ecology and Environment (1993). This raised questions about the possibility of contaminant transport from the Fulbright Landfill to North U Drive by way of water movement through the Springfield Plateau aquifer. An examination of existing water-quality data from Fulbright and Sac River landfills that was collected by SCS (1988) showed that contaminants consist mostly of metals, and to a lesser extent, volatile organic compounds. Lead was a common contaminant found in water samples from both landfills, but also present were arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, and zinc. A more complete listing of contaminants and their concentrations can be found in SCS (1988); detailed North U Drive water-quality data can be found in Ecology and Environment (1993).

In the landfills, concentrations of most of the metals were generally less than 1,000 ug/l, with the exception of zinc and, much less often, lead. At North U Drive, volatile organic compounds consisting primarily of petroleum hydrocarbons, and relatively low levels of metals, were found in water samples (Ecology and Environment, 1993). The samples were analyzed for total lead, and several wells were found to contain more than 50 ug/l total lead. To help determine the nature of the contamination problem, wells were resampled, and the water analyzed for both total metals and dissolved metals. It was found that the wells that tested high for total lead did not contain excessive dissolved lead. Most of the wells which had high total lead levels were private water-supply wells that are not regularly used. The SCS (1988) concluded that the source of the lead may be from galvanized pipes, pump or well components, or sediment.

Regardless of the possible similarities between contaminants found at the landfills and North U Drive, hydrologic data indicates that contaminant movement from either landfill to North U Drive by way of the Springfield Plateau aquifer is virtually impossible. Water-level elevations measured at North U Drive shallow monitoring well are typically 40 to 50 feet above those measured from shallow bedrock monitoring wells at the Fulbright Landfill.

The most conclusive proof that groundwater movement in the Springfield Plateau aquifer at North U Drive is toward the South Dry Sac River valley, and toward Fulbright Landfill, is the results of two water traces conducted by the Department of Natural Resources' Division of Geology and Land Survey (DGLS). Dyes injected by Kurt Holman, DGLS, into a shallow well and septic system on the North U Drive site were recovered at a spring along the South Dry Sac River opposite the Fulbright Landfill. On October 10, 1992, 5 pounds of fluorescein dye was injected into a Springfield Plateau aquifer well on the old Curtis Service Station site. This well is about 150 ft west of North U Drive deep monitoring well. It is 108 ft deep, and is known have contained high levels of petroleum hydrocarbons. Numerous springs in the area were equipped with dye-monitoring packets. Dye was recovered at North U Spring, 3,000 ft north of the injection site, 19 to 26 days after injection. Average groundwater velocity based on this was 115 ft/day to 158 ft/day. A second dye trace was conducted from a septic tank that serves Montgomery Metal Crafts (MMC) and an adjacent rental property owned by MMC. One gallon of Rhodamine WT was injected into the septic tank on August 5, 1992. The dye was recovered at North U Spring, 3,160 ft to the north, between August 27 and September 10, 1992. Travel time was between 49 and 57 days, and straight-line velocity was between 55 ft/day and 64 ft/day (SCS, 1993).

Water-level data strongly indicates that shallow groundwater movement from the North U Drive site is to the north. The dye trace data conclusively establishes that contaminants introduced into the Springfield Plateau aquifer at North U Drive will move north to North U Spring. The possibility of conditions occurring that would reverse this gradient and allow contaminants from the Fulbright Landfill to move south, beneath the South Dry Sac River, to North U Drive through the Springfield Plateau aquifer is very remote.

REFERENCES CITED

Emmett, Leo F., John Skelton, R.R. Luckey, Don E. Miller, Thomas L. Thompson, and John W. Whitfield, 1978, Water resources and geology of the Springfield area, Missouri: Mo. Dept. of Natural Resources, Division of Geology and Land Survey, Water Resources Report no. 34, 150 p.

Ecology and Environment, 1993, Draft final remedial investigation report of the North U Drive site, Springfield, Greene County, Missouri: Prepared for Mo. Dept. of Natural Resources, Hazardous Waste Program, Superfund Section, Ecology and Environment, Inc., Overland Park, KS, 254 p.

Ecology and Environment, 1992, Draft final report for Phase 2, Subphase 2 ofthe North U Drive remedial investigation, Springfield, Greene County, Missouri: Prepared for Mo. Dept. of Natural Resources, Hazardous Waste Program, Superfund Section, Ecology and Environment, Inc., Overland Park, KS, 71 p. plus appendices.

Imes, Jeffrey L., 1989, Analysis of the effect of pumping on ground-water flow in the Springfield Plateau and Ozark aquifers near Springfield, Missouri: U.S. Geological Survey, Water Resources Investigations Report 89-4079, 63 p.

Imes, Jeffrey L. and Leo F. Emmett, in press, Geohydrology and modeling analysis of the Ozark Plateaus aquifer system in Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414-F.

Middendorf, Mark A., 1990, Geologic map of the Ebenezer Quadrangle, Greene County, Missouri: Mo. Dept. of Natural Resources, Division of Geology and Land Survey, Unpublished map repository, 1:24,000.

SCS (Stearns, Conrad and Schmidt Consulting Engineers, Inc), 1988, Remedial investigation and endangerment assessment, Fulbright and Sac River landfill sites: Prepared for Springfield Steering Committee, in care of the Department of Public Works, Springfield, MO, SCS Engineers, Reston VA, 120 p. plus appendices.

Springfield City Utilities, undated, Your water system: Brochure prepared by Springfield City Utilities, 14 p.

Walton, William C., 1962, Selected analytical methods for well and aquifer evaluations: Illinois State Water Survey, Bulletin 49, 81 p.

APPENDIX A
PRIVATE WELL SURVEY

A private well survey was conducted in the study area to determine the number and location of private water-supply wells. Figure A-1 shows the area surveyed, and the locations and reference numbers of the private wells surveyed. A door-to-door survey was made, and well owners were asked to supply some basic information about their wells. Some well owners did not wish to cooperate in this survey, and others could not be contacted. Thus, there are likely several more wells in the surveyed area than are shown in table A-1.

Approximately 360 private wells were inventoried in this survey. Wells in the North U Drive area were inventoried during previous studies, and were excluded from this Survey.

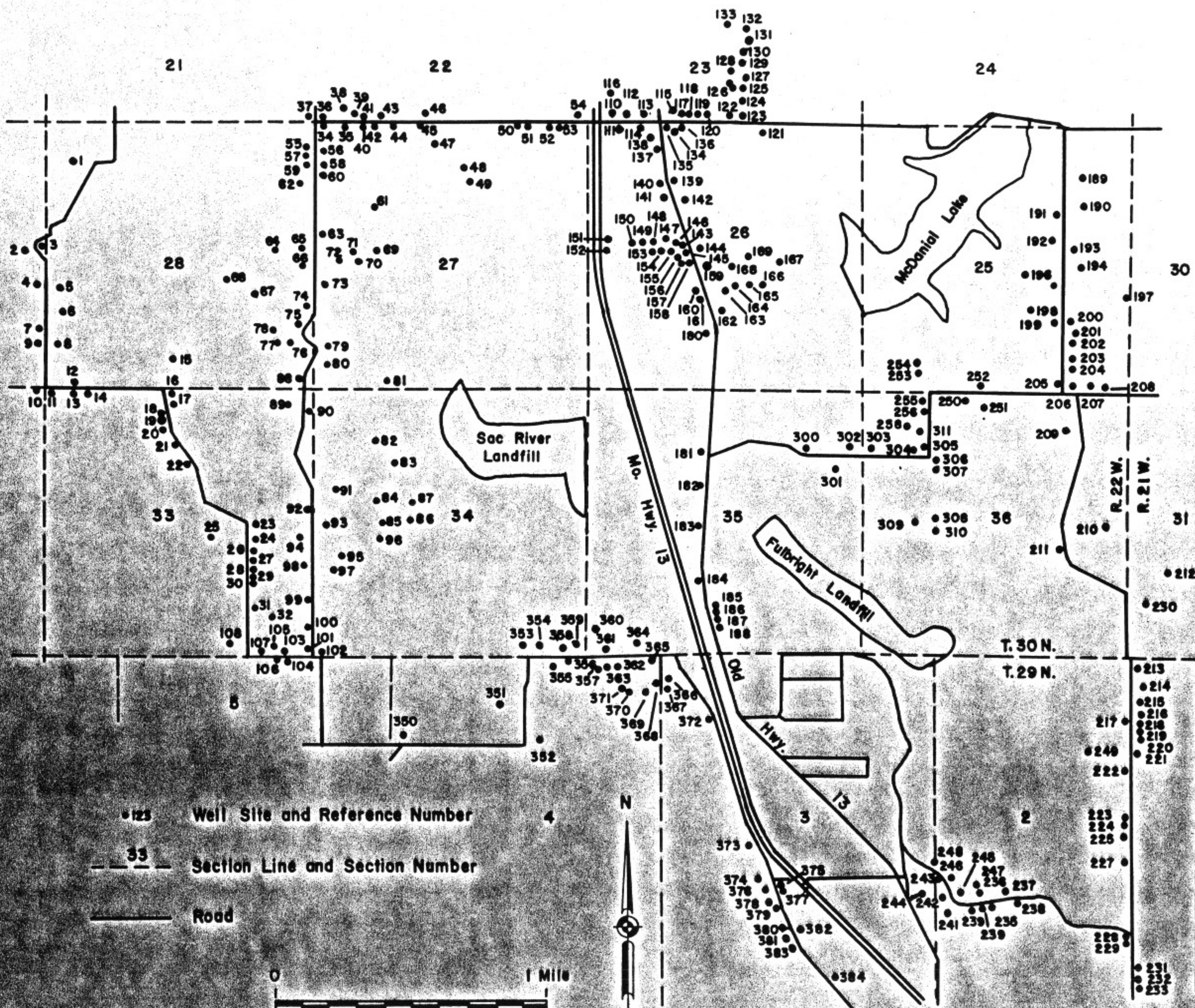

Figure A-1. *Map showing locations of private water-supply wells inventoried during this study.*

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
2	CARROLL	DAN		833-6248	RT. 20, BOX 1999-A	SPRINGFIELD	MO	65803	28	30	22
3	ANDRUS	BOB		742-5065	RT. 20, BOX 1998	SPRINGFIELD	MO	65803	28	30	22
4									29	30	22
5	INMAN	R		833-9618	RT. 20, BOX 1997	SPRINGFIELD	MO	65803	28	30	22
6									28	30	22
7	McMILLEN	ROBERT		833-6955	RT. 20, BOX 1995	SPRINGFIELD	MO	65803	29	30	22
8	BUNGE	SUSAN		833-0221	RT. 20, BOX 1975	SPRINGFIELD	MO	65803	28	30	22
9	SMITH	C			FR 125				28	30	22
10	RODINMAN			869-6926					32	30	22
11	STANFILL	BILL		833-4642	RT.20, BOX 1973	SPRINGFIELD	MO	65803	33	30	22
12	BUNGE	SUSAN		833-0221	RT. 20, BOX 1975(70)	SPRINGFIELD	MO	65803	28	30	22
13									33	30	22
14	JETER	JAMES	R		RT. 20, BOX 1965	SPRINGFIELD	MO	65803	33	30	22
15	PERTUCHE			833-2147	RT. 20, BOX 1962	SPRINGFIELD	MO	65803	28	30	22
16	VEREGGE	LAVON		833-2311	RT. 20, BOX1960	SPRINGFIELD	MO	65803	33	30	22
17	VEREGGE	LAVON		833-2311	RT. 4035 OLD BOLIVER RD.	SPRINGFIELD	MO	65803	33	30	22
18	JENKINS	SPENCER	W	833-1821	RT. 20, BOX 1950	SPRINGFIELD	MO	65803	33	30	22
19									33	30	22
20									33	30	22
21									33	30	22
22									33	30	22
23	RICE	HERBERT		833-1344	RT. 20, BOX 1910	SPRINGFIELD	MO	65803	33	30	22
24	JOHNSON	MELVIN		833-1324	RT. 20, BOX 1910	SPRINGFIELD	MO	65803	33	30	22
25									33	30	22
26	JOHNSON	MELVIN		833-1324	RT. 20, BOX 1910	SPRINGFIELD	MO	65803	33	30	22
27					RT. 20, BOX 1905				33	30	22
28					4510 N. 125				33	30	22
29	DEVINE	WAYNE		833-2753	RT. 20, BOX 1901	SPRINGFIELD	MO	65803	33	30	22
30	ASH	DAN							33	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
2	Y	437	340	1991	Y	OILY TASTE	?	?	42957	
3	Y	400?	100?	1992	Y	SEE COMMENTS	N	?		
4										
5	Y				Y	GOOD	N			
6										
7	Y	385	385	1991	Y	SULFUR,IRON	N	?		
8	Y	400	?	1978	Y	BACTERIA	N	?		
9			N							
10										
11	Y	425	?	1964	Y	GOOD	N	?		
12	Y	?	?	?	Y		N	?		
13										
14	Y	?	?	?	Y	GOOD	?	?		
15	Y	235	72	1972	Y	GOOD	N	200		
16	Y	620	350	1986	Y	GOOD	N	?		
17	Y	400?	150?	1973?	Y	?	N	?		
18	Y	152	?	55 TO 60	?	GOOD	N	?		
19										
20										
21										
22										
23	Y	353	130	1979	Y	BACTERIA	Y	90		
24	Y	?	?	1973?	Y	GOOD	N	?		
25										
26	Y	110	?	?	Y	?	Y	?		
27										
28										
29	Y	300	?	1981	?	GOOD	CIST.	?		
30										

MAP REF.#	COMMENTS
2	PLASTIC LINER 340', 4" DIA. WORK PHONE 895-6848
3	BACTERIA, SULFUR ODOR
4	CONTACT DIXEY NOLAND PECK (MARSHFIELD, 759-2394, RT 2 BOX 117)
5	LOCKED GATE, CALL AFTER 5:30. AJAX ROOFING
6	NO ANSWER
7	BLACK AND WHITE HOUSE NEXT DOOR ON 82 SERVED ALL IN AREA
8	RESIDENT
9	
10	CALL EARLY MORNING
11	
12	OWNER
13	NO ANSWER
14	.5 MILE W. OF FANTASTIC CAVERNS
15	
16	OLD DERBY WELL LOCATED ACROSS FROM BOOK STORE.
17	WANTS WELL SAMPLED. AT DOUBLE F. C. SIGN
18	
19	NO ANSWER
20	NO ANSWER
21	NO ANSWER
22	NO ANSWER
23	WANTS RESULTS, NEW LINER DEEPER, TWO WELLS PUGGED
24	WANTS RESULTS, CONDEMED HOUSE NEXT DOOR AT 110'
25	NO ANSWER AND THE DOG BITES
26	HOUSE CONDEMED, OWNER LIVES NEXT DOOR
27	NO ANSWER
28	NO ANSWER
29	CISTERN USED AS PUMP HOUSE
30	NOT INTERESTED

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
31									33	30	22
32									33	30	22
34	ZWEERINK	RANDY			'504 HARPE	SPRINGFIELD	MO	65804	27	30	22
35	MABURY	BILL		833-4804	RT. 20, BOX 2095-C	SPRINGFIELD	MO	65803	27	30	22
36									22	30	22
37	KEESLARY	GEORGE		833-3638	RT. 20	SPRINGFIELD	MO	65803	28	30	22
38	BATCHELLER	JACK			RT. 20				22	30	22
39	HOBBS								22	30	22
40									27	30	22
41	ALLEN	WALTER		833-3372	RT. 20, BOX 2097-A	SPRINGFIELD	MO	65803	22	30	22
42	BETHEUM	MORRIS			RT. 20, BOX 2097-A				27	30	22
43	DILLEY	PAUL		833-2461	RT. 20, BOX 2097	SPRINGFIELD	MO	65803	22	30	22
44	DE LOZIER				RT. 20				27	30	22
45	GANN	JOHN		833-3445	RT. 20, BOX 2097-F	SPRINGFIELD	MO	65803	27	30	22
46	MEFFER?	BILL			RT. 20, BOX 2097-I				22	30	22
47	BABCOCK								27	30	22
48									27	30	22
49	PLUMMER	DAVID		833-4677	RT. 20, BOX 2097-E	SPRINGFIELD	MO	65803	27	30	22
50	ASH	J	L		BOX 2098A				27	30	22
51	ASH	J	L		BOX 2098				27	30	22
52	RAMSEY	ALLEN		833-1080	RT. 20, BOX 210(OR A?)	SPRINGFIELD	MO	65803	27	30	22
54	BANTA				RT. 20 BOX 2110				22	30	22
55				833-2494					28	30	22
56									27	30	22
57									28	30	22
58									27	30	22
59	HUDGINS	LOYE		833-2111	5645 N. FARM RD. 129	SPRINGFIELD	MO	65803	28	30	22
60	TINDALL	LARRY		833-2111					27	30	22
61	WELSH	MIKE		833-9713	RT. 20, BOX 2302	SPRINGFIELD	MO	65803	27	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
31										
32										
34	Y	385	252	1988				100	A06861-00	
35	Y	275	20?	1979	Y	BACTERIA	N	?		
36										
37	Y	405	100	1982	Y	BACTERIA	N	?		
38										
39										
40										
41	Y	404	TO ROCK	1961	Y	GOOD	N	?		
42										
43	Y	460	45	1975	Y	GOOD	N	216		
44										
45	Y	395	160	81-82	N	GOOD	N	60 TO 90		
46										
47										
48										
49	Y	320P	320	1985?	Y	BACT. RUST	N	?		
50										
51										
52	Y	425	213	1992	Y	BACTERIA	N	120	A26853	5283
54										
55										
56										
57										
58										
59	Y	386	228?	1993	Y	GOOD	N	?		
60										
61	Y	350	155	1989	Y	?ODOR	N	170	Z01563-00	

MAP REF.#	COMMENTS
31	NO ANSWER
32	NO ANSWER
34	NO ANSWER
35	GOOD WATER SUPPLY. WHERE CAN THEY HAVE TESTING?
36	NO ANSWER
37	SEASONAL BACTERIA, THEY DONT DRINK WATER
38	
39	WANT NO INVOLVEMENT
40	NO ANSWER
41	
42	NO ANSWER
43	
44	NO ANSWER
45	CASING TO SOLID LIMESTONE
46	NO ANSWER
47	NO ANSWER
48	NOT OCCUPIED, FOR SALE BY CENTURY 21, 881-2179
49	PLASTIC LINER
50	NO ANSWER
51	NO ANSWER
52	CASED TO BEDROCK
54	NO ANSWER
55	NO ANSWER
56	NO ANSWER
57	LOCKED GATE
58	MEAN SAINT BERNARD, NO APPERANCE OF ANYONE HOME
59	
60	COUSIN HOME CALL THE 17TH
61	

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
62	SMITH	WESLEY	L	833-3717	RT. 20, BOX 2303	SPRINGFIELD	MO	65803	34	30	22
63									27	30	22
64									28	30	22
65									28	30	22
66									28	30	22
67									28	30	22
68									28	30	22
69	WELTON	SHARON	K	833-4719	RT. 20, BOX 2313	SPRINGFIELD	MO	65803	27	30	22
70	WARFORD	MIKE			RT. 20, BOX 2313	SPRINGFIELD	MO	65803	27	30	22
71									27	30	22
72									27	30	22
73									27	30	22
74									28	30	22
75									28	30	22
76	RITTERBACH	WANDA		833-0606	RT. 20, BOX 2315	SPRINGFIELD	MO	65803	28	30	22
77									28	30	22
78	FELDMAN	HARVEY		833-4756	RT. 20, BOX 2216-A	SPRINGFIELD	MO	65803	28	30	22
79	RICHARDSON	MATT		833-9429	RT.20, BOX 2316	SPRINGFIELD	MO	65803	27	30	22
80	PERRYMAN	PATRICK		833-9761	RT. 20, BOX 2318	SPRINGFIELD	MO	65803	27	30	22
81	JOHNSTON	JERRY		833-5608	RT. 20, BOX 2321	SPRINGFIELD	MO	65803	27	30	22
82	PALMER	DOUG		833-3184	RT.20, BOX 2318-1	SPRINGFIELD	MO	65803	34	30	22
83	ULRICH	LARRY		833-3512	RT. 20, BOX 2317	SPRINGFIELD	MO	65803	34	30	22
84	BURNING	JEFF		833-6232	RT. 20, BOX 2319-A	SPRINGFIELD	MO	65803	34	30	22
85									34	30	22
86									34	30	22
87	SMITH	RONDA		833-1921	RT. 20, BOX 2317-B	SPRINGFIELD	MO	65803	34	30	22
88				833-0333					28	30	22
89									33	30	22
90	RICHARDSON	FRED		833-0248	RT. 20, BOX 2324	SPRINGFIELD	MO	65803	33	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
62	Y	355	160	1989	Y	GOOD	Y	100	A15673-00	
63										
64										
65										
66										
67										
68										
69	Y	300	120	1979	Y	GAS TASTE	N	90		
70	Y	285	210	1988	Y		N	120		
71										
72										
73										
74										
75										
76	Y	87	?	1953?	Y	OK	N	?		
77										
78	Y	264	20	1984	Y	OK	N	?		
79		265	40	79-80	Y	OK	N	?		
80	Y	320	120	86 OR 87	Y	GOOD	N	200?		
81	Y	285	168	1991	Y	SULF. IRON	N	60	A25802	
82	Y	355	150	1989	Y	SULFER	N	90	A20151	
83	Y	325	84	1987	Y	GOOD	N	90	A03641-00	
84	Y	330	150	1987	Y	SULFER ODOR	N	90		
85										
86										
87	Y	600-800	?	?	Y	SULFER ODOR	N	?		
88										
89										
90	Y	297	100	1985	Y	GOOD	?	40-50		

MAP REF.#	COMMENTS
62	CAPPED CEMENT WELL CAN BREAK AND SAMPLE, REPAIR
63	MOBILE HOME, NO ANSWER
64	MOBILE HOME, NO ANSWER
65	NO ANSWER
66	NO ANSWER
67	NO ANSWER
68	NO ANSWER
69	METALLIC GAS TASTE, ALSO HAS AN ODOR
70	WANT RESULTS IF SAMPLED!
71	WANTS NO INVOLVEMENT
72	NO ANSWER
73	NO ANSWER, A-FRAME
74	NO ANSWER
75	
76	THEY DON'T DRINK CONTAMINATED WATER, WORK # 833-3800
77	MISSING SURVEY
78	
79	PUMP SET AT 185', CALL AFTER 10PM, WANTS RESULTS
80	
81	SULFER ODOR, RUSTY ORANGE STAIN, 100 GPM @ 60'
82	SULFER AFTER RAIN, HAVE WATER SOFTENER, LINE 160'
83	
84	WATER SOFTENER AND AIR INJECTOR
85	NO ANSWER
86	SHARES WELL WITH # 87
87	SHARES WELL WITH NEIGHBOR # 86
88	CALL AT 7 AM, WILLIAMS SPRING
89	NO ANSWER
90	HEARD ABOUT 60' DUG WELL

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
91									34	30	22
92	JOHNSON	MARY	V	833-1808	RT. 20, BOX 2326	SPRINGFIELD	MO	65803	33	30	22
93	ELLINGSWORTH	RON		833-4236	RT. 20, BOX 1860	SPRINGFIELD	MO	65803	34	30	22
94	FOREMAN	JOHN		833-1766	RT. 20, BOX 2331	SPRINGFIELD	MO	65803	33	30	22
95	LAWSON			833-3630	RT. 20, BOX 2332-A	SPRINGFIELD	MO	65803	34	30	22
96	THOMAS	LARRY		833-9167	RT. 20, BOX 2333-2	SPRINGFIELD	MO	65803	34	30	22
96	LINDSEY	JUNE		869-5818					34	30	22
97									34	30	22
98	VAHLDICK, SR.	ROY		833-2037	RT. 20, BOX 2335	SPRINGFIELD	MO	65803	33	30	22
99	VAHLDICK, JR.	ROY			RT. 20, BOX 2340	SPRINGFIELD	MO	65803	33	30	22
100	CLAYTON	V	S		RT. 20, BOX 2345				33	30	22
101	*								33	30	22
102	YOUNG	CHARLES	L	833-0570	RT. 20, BOX 2355	SPRINGFIELD	MO	65803	34	30	22
103	WHITE	LLOYD		833-3159	RT. 20, BOX 1882	SPRINGFIELD	MO	65803	33	30	22
104									5	29	22
105									33	30	22
106									5	29	22
107									33	30	22
108									33	30	22
109	DOUGLAS			833-4328					5	29	22
110	CARROL	LEON		833-1015	RT. 20, BOX 2120	SPRINGFIELD	MO	65803	23	30	22
111	MURFEY	ROBERT		833-3678	RT. 20 BOX 2135	SPRINGFIELD	MO	65803	26	30	22
112	OQUIMM	JAL		833-2575	RT. 20, BOX 2130	SPRINGFIELD	MO	65803	23	30	22
113	BAVA	B							23	30	22
114	CARRETT								26	30	22
115	APPL	GEORGE		833-1199	RT. 5, BOX 473	SPRINGFIELD	MO	65803	23	30	22
116									23	30	22
117	RANDOLF	R	L	833-3279	RT. 5, BOX 475	SPRINGFIELD	MO	65803	23	30	22
118	WIRTH	JOHN		833-9475	RT. 5, BOX 476	SPRINGFIELD	MO	65802	23	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
91										
92	Y	400	20	1969	Y	GOOD	N	?		
93	Y	350-4	?	1949	Y	GOOD	N	?		
94	Y	499	100?	1961	•	OK	N	100?		
95	Y	435	?	1973?	Y	DIESEL?	N	?		
96	Y	?	?	?	Y	BACT. COLIFORM	N	?		
96										
97										
98	Y	120?	20?	1940	Y	?	N	6		
99										4860?
100										
101										
102	Y	525	250?	1971	Y	GOOD	N	?		
103	Y	510	180?	1980	Y	GOOD	Y	?		
104										
105										
106										
107										
108										
109										
110	Y	400	51	1938?	Y	PRESSURE SYST.	N	?		
111	Y	400?	TO ROCK	1966	Y	BACTERIA?	Y	240		
112	Y	250-255	30	1948	Y	OK	N	?		
113										
114										
115	Y	370	TO ROCK	40-50'S	N	OK	N	50-70		
116										
117	Y	P500	?	1968?	N	OK	Y	?		
118	Y	?	?	?	Y	OK	Y	?		

MAP REF.#	COMMENTS
91	NO ANSWER, POOL
92	RENTAL HOUSE RT 20 BOX 1860, RON ELLINGSWORTH
93	OWNER MARY V. JOHNSON
94	NEXT 4 HOUSES SHARE WELL. *NEED PERMISSION FROM OTHERS
95	NEXT 4 HOUSES SHARE WELL, DIESEL KEROSENE ODOR?
96	SHARES WELL WITH 2 NEIGHBORS
96	PREVIOUS RESIDENT
97	LOCKED GATE
98	HAVE CHLORINATOR, SON JR. LIVES NEXT DOOR
99	NO ANSWER
100	NO ANSWER
101	VACANT SEE # 103
102	
103	WELL NEXT DOOR 300'? CAN SAMPLE IF WE CAP IT, UNDESIDED?
104	NO ANSWER
105	NO ANSWER
106	BEING BUILT, DRILLER JEFF MESSENGER 862-7675
107	WANTS NO INVOLVEMENT
108	NO ANSWER
109	CALL AFTER 6:30 PM
110	IN 1958 A PRESSURE SYSTEM WAS INSTALLED, DRILLED DEEPER
111	COVERED WELL 212', SWL 146', SHARES WELL NEXT DOOR
112	IN THE 50'S MANY WELLS IN AREA REDRILLED, LAKE MCDANIEL?
113	NO ANSWER
114	NO ANSWER
115	HOUSE NEXT DOOR NEVER HAD WATER, SHARED HIS WELL
116	IN COURT, NO OCCUPANT, CONTACT BILLY THOMSON
117	A 65' WELL WENT DRY AND WAS FILLED
118	ABANDONED WELL, OWNERS THE COMSTOCK'S AT WHITE PILLAR HOUSE

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
119	BODINE	BERTHA		833-3180	RT. 5, BOX 477	SPRINGFIELD	MO	65803	26	30	22
120	TAYLOR	FOREST		833-4624	RT. 5, BOX 477	SPRINGFIELD	MO	65803	23	30	22
121									26	30	22
122	COOPER	HUGH		833-4802	RT. 5, BOX 478 BB	SPRINGFIELD	MO	65803	23	30	22
123									23	30	22
124	MCGINNIS								23	30	22
125	DILLARD	JAMES	A	833-1353	RT. 5, BOX 2001	SPRINGFIELD	MO	65803	23	30	22
126	MORTON	JAY		833-2070	RT. 5, BOX 2003	SPRINGFIELD	MO	65803	23	30	22
127	HARMON	DWAINE		833-1076	RT. 5, BOX 2005	SPRINGFIELD	MO	65803	23	30	22
128	DOTY	JESSE		833-2625	RT. 5, BOX 2015	SPRINGFIELD	MO	65803	23	30	22
129	MARTIN	PAUL		833-2256	RT. 5, BOX 2007	SPRINGFIELD	MO	65803	23	30	22
130									23	30	22
131									23	30	22
132	WALLACE	CHARLES	R	833-4822	RT. 5, BOX 2016	SPRINGFIELD	MO	65803	23	30	22
133									23	30	22
134	WILLIAMS	TERRY		833-5720	5760 N HWY 13	SPRINGFIELD	MO	65803	26	30	22
135	KIENER	JOHN		833-5301	RT. 5, BOX 470	SPRINGFIELD	MO	65803	26	30	22
136									23	30	22
137				833-9058					26	30	22
138									26	30	22
139									26	30	22
140									26	30	22
141	LIDSON	JOHN		833-2377					26	30	22
142	SEDERBURG	NANCY		833-3573	RT. 5, BOX 463-B	SPRINGFIELD	MO	65803	26	30	22
143									26	30	22
144	BOATMAN	DENNIS		833-1300	RT. 5, BOX 467-A	SPRINGFIELD	MO	65803	26	30	22
145									26	30	22
146									26	30	22
147									26	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
119	Y	350	180	40-50'S	Y	OK	N	?		
120	Y	210?	?	?	Y	OK	N	?		
121										
122	Y	440	?	LATE 60'S	Y	OK	N	?		
123										
124										
125	Y	410	35	1962	Y	BACTERIA	N	MORE 200		
126	Y	450	?	1968?	Y	OK	N	100?		
127	Y	500?	?	?	?	OK	N	?		
128	Y	520	30	1993	?	OK	N	150		
129	Y	395	40	1977	Y	FUNNY TASTE	N	?		
130										
131										
132	Y	450	75	1976	Y	RED COLOR	N	?		
133										
134	Y	?	?	?	Y	OK	?	?		
135	Y	329	?	1984	Y	BROWN COLOR	N	122		
136										
137										
138										
139										
140										
141										
142	Y	300?	?	1985	Y	OK	N	?		
143										
144	Y	?	?	1986	Y	SOFTENER	N	?		
145										
146										
147										

MAP REF.#	COMMENTS
119	HOUSE BUILT IN 1936, WELL DEPTH 350-375'
120	
121	NO ANSWER
122	
123	WANTS NO INVOLVEMENT
124	NO ANSWER
125	
126	
127	RECASED ABOUT 2 YEARS AGO, NEW PUMP
128	PUMP 400', REDRILLED IN 1993, LINER AT 260'
129	PUMP APPROX. 300', WANTS REPORT WHEN COMPLETED
130	MOBILE HOME, NO ANSWER
131	NO ANSWER
132	OCCASIONAL DEEP RED COLOR
133	NO ANSWER
134	CONTACT SPIKE TEMPLE AND LEAVE MESSAGE. SHARE WITH ANOTHER
135	LANDLORD
136	NO ANSWER
137	GLIDEWELL BAPTIST PRESCHOOL, CONTACT MRS. MURREY
138	BAPTIST PARISH, SHARES WELL WITH SCHOOL, VACANT
139	NO ANSWER, ROTWIELLER DOG
140	NO ANSWER
141	CALL EVENINGS
142	DRILLED BY DOUG GARDENER
143	NO ANSWER
144	MANY SPRINGS ALONG HILLSIDE
145	NO ANSWER
146	NO ANSWER
147	CALL JEROLD MCMILLON, WILLARD MO

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
148									26	30	22
149									26	30	22
150									26	30	22
151									26	30	22
152									26	30	22
153	HICKS	MABEL		833-1132	RT. 5, BOX 466-A	SPRINGFIELD	MO	65802	26	30	22
154									26	30	22
155									26	30	22
156	RIGGS	RICK		833-4245	RT. 5, BOX 466-G	SPRINGFIELD	MO	65803	26	30	22
157	MURRAY	MARK		833-3259	RT. 5, BOX 458	SPRINGFIELD	MO	65803	26	30	22
158									26	30	22
159									26	30	22
160	LOUDER BAUGH	BEVERLY		833-0401	RT. 5, BOX 463	SPRINGFIELD	MO	65803	26	30	22
161									26	30	22
162	MURREY								26	30	22
163	MURREY	MAX		833-3650	RT. 5, BOX 460	SPRINGFIELD	MO	65803	26	30	22
164	LEPPER	ROBERT		833-5346	RT. 5, BOX 462	SPRINGFIELD	MO	65803	26	30	22
165									26	30	22
166	FISHER			833-5267	RT. 5, BOX 462-4	SPRINGFIELD	MO	65803	26	30	22
167	NICHOLSON	JOE		UNLISTED	RT. 5, BOX 462-3	SPRINGFIELD	MO	65803	26	30	22
168	DAVISON	DAVE		833-6333	2068 S SUPREMA	SPRINGFIELD	MO	65807	26	30	22
169	CARPENTER	JOE		833-3357	RT. 5, BOX 462-2	SPRINGFIELD	MO	65803	26	30	22
180									26	30	22
181									35	30	22
182									35	30	22
183	BRUFFETT	RUSSELL		833-4040	RT. 5, BOX 437	SPRINGFIELD	MO	65803	35	30	22
184	BRAZEAL	EARNEST		833-N621	RT. 5, BOX 436	SPRINGFIELD	MO	65803	35	30	22
185									35	30	22
186									35	30	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
148										
149										
150										
151										
152										
153	Y	?	?	?	Y	OK	N			
154										
155										
156	Y	350?	?	?	Y	OK	N	?		
157	Y	365	?	2971	Y	OK	N	60?		
158										
159										
160	Y	?	?	?	Y	?	?	?		
161										
162										
163	Y	325	210	1993	Y	OK	N	60		
164	Y	?	?	1979	Y	OK	N	?		
165										
166	Y	1036?	?	1980	Y	OK	N	?		
167	Y	420	80-100	1979	Y	OK	Y	?		
168	Y	365	231	1990				120	A20390	
169	Y	377	59	1979	N	OK	Y	255?		
180										
181										
182										
183	Y	300?	100?	?	Y	OK	N	50?		
184	Y	50-60	?	?	Y	OK	N	?		
185										
186										

MAP REF.#	COMMENTS
148	NO ANSWER
149	NO ANSWER
150	NO ANSWER
151	NO ANSWER
152	NO ANSWER CARRYALL T.
153	CONTACT MESSENGER DRILLING, 732-7369, DAVE DAVISON 833-6333
154	NO ANSWER
155	CALL KEVIN FLETCHER
156	STATED THAT ALL WELLS RUN WITHIN ABOUT 100' OF EACH OTHER
157	
158	NO ANSWER
159	RECOMMENDED READING NO TRESSPASSING SIGNS
160	
161	NO ANSWER
162	SON OF MAX MURREY NEXT DOOR AT 163
163	FEZZEL DRILLED ACROSS ROAD.
164	GOOD PRESSURE, MOST HOUSES IN AREA BUILT 1979, PUMP 225'
165	NO HOUSE
166	CAN CALL LATER DURING THE DAY
167	HAND DUG WELL 30' TO 40', WANT RESULTS OR REPORT MAILED
168	LOCKED GATE
169	SHALLOW CAPPED, NO PUMP, NO SAMPLE
180	NO ANSWER
181	NO ANSWER
182	NO ANSWER
183	SPRING WITH OPENING IN CASING ABOUT 50' DOWN
184	
185	NO ANSWER
186	NO ANSWER

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
187									35	30	22
188	BURGESS JR.	CHARLES	E	833-3042	RT. 5, BOX 430	SPRINGFIELD	MO	65803	35	30	22
189	YATES				RT. 5, BOX 5794	SPRINGFIELD	MO	65803	25	30	22
190									25	30	22
191	DICKENS	ROY							25	30	22
192	HESS	JOHN		833-6501	RT. 5, BOX 661	SPRINGFIELD	MO	65803	36	30	22
193	COPENING	KATIE		833-2719	RT. 5, BOX 662, 5420 N GRANT	SPRINGFIELD	MO	65803	36	30	22
194	ROY	JOHN		833-1928	5324 GRANT	SPRINGFIELD	MO	65803	36	30	22
195	EARWOOD	TIM			BOX 664				36	30	22
196	BAKER	THOMAS	C	833-2513	5351 GRANT	SPRINGFIELD	MO	65803	36	30	22
197	PEIFFER				RT. 5, BOX 667, 5240 GRANT	SPRINGFIELD	MO	65803	25	30	22
198	JENNINGS	CHARLIE			RT. 5, BOX 668, 5279 GRANT	SPRINGFIELD	MO	65803	25	30	22
199	WILLIAMSON	H	F		RT. 5, BOX 669	SPRINGFIELD	MO	65803	25	30	22
201	DICKEY	JIM		833-3247	5150 GRANT	SPRINGFIELD	MO	65803	25	30	22
202	THIEMAN	L	D		5124 GRANT	SPRINGFIELD	MO	65803	25	30	22
203	FOSTER	STEVE							25	30	22
204	GIBSON	NANCY		833-5118	RT. 5, BOX 671-A-G	SPRINGFIELD	MO	65803	25	30	22
205	OWENS	DEBBIE		833-9207	RT. 5, BOX 671-E	SPRINGFIELD	MO	65803	25	30	22
206	WEDMORE	MARGRET		833-4169	RT. 5, BOX 677-B	SPRINGFIELD	MO	65803	25	30	22
207	CROSS	JERRY		833-0501					25	30	22
208	JONES	DENNIS		833-9413	RT. 5, BOX 678-D	SPRINGFIELD	MO	65803	25	30	22
209	OWEN	MELVIN		833-3712	RT. 5, BOX 677	SPRINGFIELD	MO	65803	36	30	22
210	MOTTA	BILL		833-2426	4650 N GRANT	SPRINGFIELD	MO	65803	36	30	22
211	OWENS								36	30	22
212	DATEMA?	HANK			4420 N GRANT	SPRINGFIELD	MO	65803	31	30	21
213	PETERSON				RT 5 BOX 690				2	29	22
214	SLIGER	DEANNA		833-3400	4104 N GRANT	SPRINGFIELD	MO	65803	2	29	22
215	PETERSON	DALE							2	29	22
216	SKIDMORE	HERB		833-1607	RT. 5, BOX 693, 4050 N GRANT	SPRINGFIELD	MO	65803	2	29	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
187										
188	Y	110	?	1946	Y	OILY, GREASY	N	?		
189										
190										
191										
192	Y	?	?	>5 YEAR	Y	OK	N	?		
193	Y	>240	?	1980	Y	OK	N	?		
194	Y	?	?	?	Y	OK	N			
195										
196	Y	327	95	1978	Y	OK	N	?		
197										
198										
199										
201	Y	>400	?	1971	N	OK	Y	?		
202										
203										
204	Y	>250	?	>20 YEARS	Y	OK	N	?		
205	Y	?	?	?	Y	OK	N			
206	Y	>600	?	1990	Y	OK	N	?		
207										
208	Y	>400	?	1953	Y	OK	N	?		
209	Y	?	?	1975	Y	OK	N			
210	Y	?	?	1993	Y	OK	N	?		
211										
212										
213										
214	Y	200?	?	?	Y	OK	N	?		
215										
216	Y	500	?	1973	N	OK	N			

MAP REF.#	COMMENTS
187	CITY WATER
188	NOT USED AND COVERED, TESTED POSITIVE FOR MTBE'S. GOOD YIELD
189	NO ANSWER
190	NO ANSWER
191	NO ANSWER
192	
193	REDRILLED 1980
194	
195	NO ANSWER
196	
197	NO ANSWER
198	NO ANSWER
199	NO ANSWER
201	
202	NO ANSWER? WORKS FOR CITY UTILITIES
203	NO ANSWER
204	
205	
206	TWO MOBILE HOMES USE SAME WELL, DRILLED FROM 400' TO >600'
207	PHONE # GIVEN BY MR JONES #208
208	
209	
210	CALL BILL EVENINGS FOR MORE INFO.
211	NO ANSWER
212	NO ANSWER
213	NO ANSWER
214	
215	PER MRS SKIDMORE #216
216	

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
217	TRIPLETT				694 N GRANT	SPRINGFIELD	MO	65803	2	29	22
218	POLODNA				4030 N GRANT	SPRINGFIELD	MO	65803	2	29	22
219	WILLIAMS	CHARLES		833-2235	RT. 5, BOX 695, 4014 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
220	MORRIS	REX							2	29	22
221	LYONS	STEVE		833-1747	RT. 5, BOX 700, 3930 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
222					3741 N GRANT	SPRINGFIELD	MO	65803	2	29	22
223	HALL	ELIZIBETH		833-0683	RT. 5, BOX 705, 3725 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
224	UMLAUF	CLEO		833-3718	3703 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
225	WHITE	DON			723 BEVERLY HILLS DR.	SPRINGFIELD	MO	65803	2	29	22
226	MONTGOMERY				3621 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
227	WOBBEMA	PEGGY		833-5072	3500 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
228	HETRICK	JAMES		833-3189	3303 N GRANT.	SPRINGFIELD	MO	65803	2	29	22
229					3247 N GRANT.				2	29	22
230									31	30	21
231	ELTRINGHAM	SANDY		833-0901	3270 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
232					3246 N. GRANT				2	29	22
233					3238 N. GRANT				2	29	22
234	PALMERTON	ROGER		833-3219	3215 N. GRANT	SPRINGFIELD	MO	65803	2	29	22
235	BAKER	BERNARD	O	833-3758	1340 W. FR. 102 STAGECOACH	SPRINGFIELD	MO	65803	2	29	22
236	LONGSTREET	CURTIS		833-5844	1401 W. STAGECOACH	SPRINGFIELD	MO	65803	2	29	22
237	BRADLEY	DEL		833-4411	8533 N. FRANKLIN	SPRINGFIELD	MO	65803	2	29	22
238	POTTENGER	DAVE		833-3298	1234 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
239	MATHIS	WOODY		833-0962	1420 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
240	MILL TAVERNS	SUSAN		833-9992	1414 W, STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
241	WALTERS	PRESTON		833-2520	1440 W. STAGECOACH	SPRINGFIELD	MO	65803	2	29	22
242	JOHNSON	FRED		833-3733	1522 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
243	JOHNSON	KENNETH		833-2131	1524 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
244	GORHAM	CLIFF		833-4725	1600 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	3	29	22
245	WAITE	ARTHUR	L	833-1089	1439 W STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
217										
218										
219	Y	445	80	1975	Y	IRON	N	?		
220										
221	Y	480	?	1971	Y	OK	N	?		
222										
223	Y	360	LESS 60	1945	Y	BAD	N	?		
224	Y	?	?	1948	Y	OK	?	?		
225	N						?			
226										
227	Y	?	?	1980?	Y	OK	N	?		
228	N						N			
229										
230										
231	N						Y			
232										
233										
234	N						N			
235	N						Y			
236	N						Y			
237	N						N			
238	N						N			
239	N						N			
240	N						N			
241	N						N			
242	N						N			
243	N						N			
244	N						N			
245	N						N			

MAP REF.#	COMMENTS
217	NO ANSWER
218	NO ANSWER
219	
220	SHARES WELL WITH # 219?
221	QUARTER HOME RANCH
222	NO ANSWER
223	ANIMAL WASTE? AFTER A LOT OF RAIN
224	
225	MRS. WHITE SAID ONLY CITY WATER IN NORTHERN HILLS SUBDIVISION
226	NO ANSWER
227	
228	SPRINGFIELD CITY LIMIT STARTS WITH THIS HOUSE, S. ON GRANT AVE.
229	NO ANSWER
230	NO ANSWER
231	OLD HOME HAS WELL
232	NO ANSWER
233	NO ANSWER
234	LIVED SINCE 1920. HOMES IN AREA ALWAYS CITY WATER
235	CITY WATER
236	CITY WATER
237	CITY WATER
238	CITY WATER
239	CITY WATER
240	CITY WATER
241	CITY WATER
242	CITY WATER
243	CITY WATER
244	CITY WATER
245	CITY WATER

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
246	WAITE	ARTHUR		NONE	1441 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
247	BRAKEBILL	LEROY			1402 W. STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
248	BUCHANAN	CHARLES		833-1174	RT. 20, STAGECOACH DR.	SPRINGFIELD	MO	65803	2	29	22
249					990 W. LYONS	SPRINGFIELD	MO	65803	2	29	22
250	NICHOLSON	MARY		833-5583	RT. 5, BOX 671-I	SPRINGFIELD	MO	65803	36	30	22
251	RACE	BILL		833-6759	RT. 5, BOX 671-H	SPRINGFIELD	MO	65803	36	30	22
252	WELLS	BILL			RT. 5, BOX 672-	SPRINGFIELD	MO	65803	25	30	22
253	BAKER	DAVE		833-9458	RT. 5, BPX 673-D	SPRINGFIELD	MO	65803	25	30	22
254	BAKER	W	L	833-2989	RT. 1, BOX 1225	SPRINGFIELD	MO	65803	25	30	22
255	BRUCE	JAMES		833-5653	RT. 5, BOX 674	SPRINGFIELD	MO	65803	36	30	22
256					RT. 5, BOX 674-A	SPRINGFIELD	MO	65803	36	30	22
265	NELSON								35	30	22
301	BROWN	MIKE		833-2544					35	30	22
302	BARNES	DONNA		833-2231					36	30	22
303	COFFMAN	CRISS		833-6481	RT.5,BOX 450-A	SPRINGFIELD	MO	65803	36	30	22
304	MCALLISTER	CLINT		833-4311	RT. 5, BOX 675	SPRINGFIELD	MO	65803	36	30	22
305									36	30	22
306	MILLS	RICK		833-5218	RT. 5, BOX 676-B	SPRINGFIELD	MO	65803	36	30	22
307	MILLS	ERNEST		833-0417	RT. 5, BOX 676	SPRINGFIELD	MO	65803	36	30	22
308	MANN	ANTHONY		833-5116	RT. 5, BOX 675-J	SPRINGFIELD	MO	65803	36	30	22
309	RAGSDALE	ROY		833-4758	RT. 5, BOX 675-G	SPRINGFIELD	MO	65803	36	30	22
310	COOPER	JOHN	E	833-2455	RT. 5, BOX 675-H	SPRINGFIELD	MO	65803	36	30	22
311	BOLIN	PAUL		833-4865	RT.5, BOX 674-D	SPRINGFIELD	MO	65803	36	30	22
350	ROYAL				3471				4	29	22
351	KLINGNER SR.	J	B						4	29	22
352	HENDRIX	DEAN		833-0971	P.O. BOX 3474, 4002 FR. 94	SPRINGFIELD	MO	65808	4	29	22
353	DRASCHIL	LEONARD		833-9190	3035 SPRING CREEK RD.	SPRINGFIELD	MO	65803	34	30	22
354	HENDERSON	DONALD	A						34	30	22
355									4	29	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
246	N						N			
247							Y			
248	N						?			
249										
250	Y	400?	?	1950'S	Y	OK	Y	?		
251	Y	?	?	?	Y	OK	N	?		
252	Y	?	?	?	Y	OK	N	?		
253	Y	600	100-150	1989	Y	OK	N	?		
254	Y	460	?	1940'S	Y	OK	N	?		
255	Y	500	?	?	Y	OK	N	?		
256										
265										
301										
302										
303	Y	?	?	?	?	DON'T DRINK	?	?		
304	Y	375	?	1984	Y	OK	N	?		
305										
306	Y	400	?	1940'S	Y	OK	N	?		
307	Y	285	55	1955	Y	OK	N	?		
308	Y	470?	?	?	Y	OK	N			
309	Y	550	?	?	Y	CHLORINATOR	N	?		
310	Y	605	315	1991	Y	IRON COLOR	Y	180?		
311	Y	405	280	1989	Y	SULFER ODOR	N	120	A10779-00	
350										
351										
352	Y	?	?	?	Y	BACTERIA	N			
353	Y	450-475	?	79-80	Y	ODOR	N	240		
354										
355	Y	396	?	?	N	OK	N	?		

MAP REF.#	COMMENTS
246	CITY WATER
247	INFO. FORM #235. CITY WATER
248	CITY WATER
249	NEW SUBDIVISION WITH CITY UTILITIES W. ON FR. 96
250	OTHER WELL NEXT TO RED BARN
251	
252	
253	
254	
255	
256	NO ANSWER
265	NO ANSWER
301	CALL EVENINGS. WILL BE BACK MONDAY.
302	DID NOT KNOW. PREVIOUS OWNER CHARLES NELSON
303	HOUSE 7 YEARS OLD. PREVIOUS HOUSE BURNED. AFTER 5PM.
304	
305	OLD VACANT HOUSE, PROBABLY HAS ABANDONED W.
306	
307	
308	
309	PUMP SET AT 500'?
310	ABANDONED WELL FILLED, WAS 463'
311	IRON SULFITES?
350	NO ANSWER
351	NO ANSWER
352	SHARES WELL WITH DORATHY JOHNS 621 W CURR (UNLISTED #)
353	BAD ODOR LIKE SOMETHING DIED
354	
355	SHARES WELL WITH NEIGHBOR, LOW OPINION OF STATE LABORATORIES

MAP REF.#	RESIDENTS LAST NAME	RESIDENTS FIRST NAME	RES. M.I.	PHONE NUMBER	ADDRESS	CITY	ST.	ZIP	SEC	TWN	RNG
356									4	29	22
357									4	29	22
358	MCMANEMIN			833-4325	2941 W. SPRING CR. RD.	SPRINGFIELD	MO	65803	34	30	22
359	HENLEY	IRA		732-8234					34	30	22
360	ZIMMERMAN	DAVE		833-4398					35	30	22
361	PIKER	CHARLOTTE		833-1455	RT. 20, BOX 428	SPRINGFIELD	MO	65803	35	30	22
362									4	29	22
363	KIRK	GREG		833-5503	2864 W. SPRING CREEK RD.	SPRINGFIELD	MO	65803	4	29	22
364	SNEED	BEN			2675 SPRING CR. RD.	WILLARD	MO	65781	35	30	22
365									4	29	22
366	TUMMONS	WILLIAMS		833-3176	4012 N. FULBRIGHT	SPRINGFIELD	MO	65803	3	29	22
367	GATELEY	PHIL		833-4762	4083 N. FULBRIGHT, RT. 20	SPRINGFIELD	MO	65803	3	29	22
368	KELLY	GERRY		833-6460	2721 BONITA	SPRINGFIELD	MO	65803	4	29	22
369	KRASSER								4	29	22
370									2	29	22
371				UNLISTED	2930 W BONITA	SPRINGFIELD	MO	65803	4	29	22
372	BOUTWELL				3951				3	29	22
373									3	29	22
374	SCHOOL								3	29	22
375									3	29	22
376	HICKS	NORMAN	B	833-1771	3537 N. BOLIVER RD.	SPRINGFIELD	MO	65803	3	29	22
377									3	29	22
378									3	29	22
379	EASTS	CATHERINE		833-1393	3505 N. OLD BOLIVER RD.	SPRINGFIELD	MO	65803	3	29	22
380	MILLER	ANN		833-4959	3445 N. BOLIVER RD.	SPRINGFIELD	MO	65803	3	29	22
381	JOHNES	MELVIN	R	833-1033	3427 OLD N. BOLIVER RD.	SPRINGFIELD	MO	65803	3	29	22
382	MONTGOMERY								3	29	22
383					3365				3	29	22
384				833-2969	3260				3	29	22

MAP REF.#	WELL? Y/N	TOTAL DEPTH	CASING DEPTH	YEAR INSTAL.	CAN WE SAMPLE	WATER QUALITY	OTHER WELL?	STATIC WATER L.	WELL RECORD	WELL LOG
356										
357										
358	Y	664?	?	?	Y	?	N	?		
359										
360										
361	Y									
362										
363	Y	?	?	1979	Y	OK	N	?		
364	Y	480	232	1990				120	A20558	
365										
366	Y	540	360	1989	Y	OK	N	150	REF. 41082	
367	Y	500	180	1987	Y	BACTERIA	N	90		
368	Y	561	261	1991	Y	OK	N	?	A20399	
369	Y									
370										
371	Y	280	?	1985	Y	BACTERIA	N	?		
372										
373										
374										
375										
376	Y	380	?	1953	Y	OK	N			
377										
378										
379	Y	>300	?	48-50	Y	OK	N	?		
380	Y	?	?	?	Y	OK	N	?		
381	Y	550	?	1950?	Y	OK	N	150		
382										
383										
384										

MAP REF.#	COMMENTS
356	NO ANSWER
357	NO ANSWER
358	HOUSE BUILT 1929. HAS SALT AND FILTER SYSTEMS
359	HOUSE BEING BUILT
360	CALL AFTER 6:30 PM
361	DR PIKER OFFICE # 836-3555, THEY ARE SEPERATED
362	NO ANSWER
363	
364	NO ANSWER
365	FOUNDATION - UNDER CONSTRUCTION
366	
367	OLD HOME SITE ACROSS RD WITH ABANDONED W. CONT. BUILDER OF FOUNDATION
368	ABANDONED W ACROSS RD, DALE BORTER, OK TO SAMPLE?
369	CALL GARY KRASSER 833-2577
370	NO ANSWER
371	
372	NO ANSWER
373	NO ANSWER, NEXT TO SCHOOL
374	CITY WATER
375	CITY WATER
376	CONTACT OWNER BEFORE SAMPLE, WANTS TO BE THERE
377	CITY WATER
378	CITY WATER
379	POSSIBLE WELL ON HICKS PROPERTY, # 376
380	
381	SHARES WELL WITH NEIGHBOR WHO IS NOT RESIDING
382	ABANDONED HOUSE HAS WELL USED BY ADJACENT HOME
383	NO ANSWER
384	CALL AFTER 5PM